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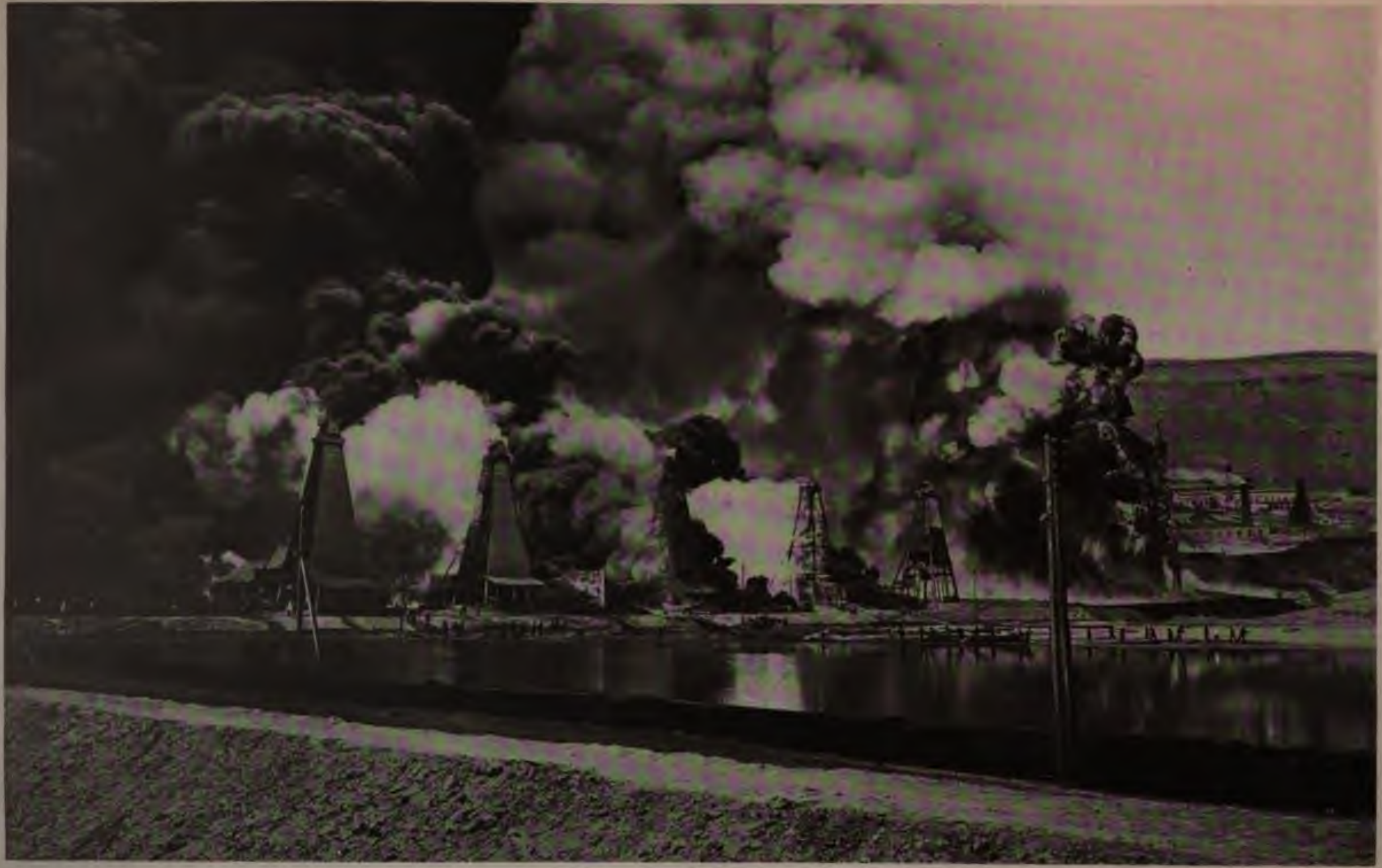
THE OIL FIELDS OF RUSSIA



A Fire on the Bibi-Eibat Oil Field.

(In 1903.)

THE

OIL FIELDS OF RUSSIA

AND

THE RUSSIAN PETROLEUM INDUSTRY

A PRACTICAL HANDBOOK ON THE EXPLORATION EXPLOITATION, AND MANAGEMENT OF RUSSIAN OIL PROPERTIES

INCLUDING

NOTES ON THE ORIGIN OF PETROLEUM IN RUSSIA
A DESCRIPTION OF THE THEORY AND PRACTICE OF LIQUID FUEL
AND A TRANSLATION OF
THE RULES AND REGULATIONS CONCERNING RUSSIAN OIL PROPERTIES

BY

A. BEEBY THOMPSON, A.M.I.MECH.E.

LATE CHIEF ENGINEER AND MANAGER OF THE EUROPEAN PETROLEUM COMPANY'S RUSSIAN OIL PROPERTIES

WITH NUMEROUS ILLUSTRATIONS AND PHOTOGRAPHIC PLATES AND A MAP OF THE BALAKHANY-SABOONTCHY-ROMANY-ZABRAT, AND BIBI-EIBAT OIL FIELDS

NEW YORK: D. VAN NOSTRAND COMPANY
23 MURRAY AND 27 WARREN STREETS
LONDON: CROSBY LOCKWOOD AND SON
1904

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To

MY FATHER

BEEBY THOMPSON, F.C.S., F.G.S.

TO WHOSE

SCIENTIFIC ATTAINMENTS AND KNOWLEDGE

I OWE SO MUCH

PREFACE

When I went to Baku in 1898, to take up an appointment with the European Petroleum Company, I was surprised to find there was no book obtainable in the English language that would supply information of a practical nature concerning the Russian oil fields. Further inquiry showed that neither Russia nor any other country could furnish such a volume. Considering the importance and magnitude of the Russian petroleum industry, this disclosure came as a great surprise. It necessitated, moreover, private investigation and practical study in every department connected with an oil property, absorbing much time which might have been saved had the results of former students' researches been available.

At the outset, I never suspected that the duty of producing such a volume as the present would devolve upon myself. My first idea was to publish some notes and results of study, in a small volume, for the assistance of newcomers to the oil fields; but I soon discovered that it was difficult to confine myself to the limits of a few notes, if the end in view was to be attained, and the proposed small volume has now grown to the dimensions of a treatise. Some friends, also, were responsible for the expansion of the work, as they repeatedly impressed upon me the desirability of giving to the English public a view of the conditions of life and enterprise prevailing in the Russian oil fields, and at least an outline of the general conduct of the industry established there as the result of the working of the oil.

Scattered throughout the work are many expressions of views, the authorship whereof cannot be individually acknowledged, or, in some cases, even traced, and I must request the reader's forbearance if upon particular points my personal opinions appear to be dogmatically advanced. On all disputable points my aim has been to give fairly the conclusions held by the most competent and intelligent authorities of the Russian oil fields.

In the introductory chapter the commercial aspect of the Russian oil industry is briefly and frankly discussed, and a summary given of the views of those best able to judge of this complicated and most interesting business; and it is hoped that the account given of several trying years will enable shareholders in Russian oil companies to attain to a better understanding of the course of events which brought about the recent acute crisis in their affairs. In the succeeding chapters I have divided up the subjects as much as possible for the purpose of ready reference, and, my aim having been to make each chapter complete in itself, a certain amount of repetition has been unavoidable. Tables have been interspersed amidst the text which should aid engineers and managers in estimations of cost and other calculations of common occurrence.

The statistics have been compiled from the official returns of the Baku Association of Naphtha Producers, and where they are presented in tabular form it is hoped they will be found to be clear and lucid, and to give at a glance the details they are intended to show. In some cases it has been impossible to make the official figures agree, but, as I had no means of ascertaining where the errors arose, I have been compelled to leave them uncorrected. Many of the results are reproduced graphically, as that form of representation gives a means of illustrating details and peculiarities which bare figures may fail to convey to the mind; and in some of the more important tables blank spaces have been left, which will enable the reader who may maintain his interest in the subject to keep his tables up to date.

In the illustrations, my aim has been to make them of practical value, and no apology, I think, is necessary for the numerous reproductions of photographs, although they are not always specially referred to in the text, as they cannot fail to give the reader who is unacquainted with the oil fields a vivid impression of the characteristics of those regions and of the prevailing phenomena.

The comprehensive scope of the work is indicated on the title-page, and as no effort has been wanting to achieve the aims there set forth, and no pains spared by either myself or the Publishers in the production of a worthy volume, I hope the work may prove not only a treatise of practical value to young engineers and others who may be directing their attention to the Russian oil fields, but also a useful manual for investors and shareholders, a trustworthy guide for travellers and explorers in oil regions, and a welcome work of reference to the man of business and the general reader.[*]

In the preparation of the volume, I have not only endeavoured to give the results of my own observation and experience, but have consulted all available books of reference, giving due acknowledgment where required. If it happen that I have not in any case acknowledged the source of information for which I am indebted to others, I crave pardon for the inadvertence. It will be found, however, I am happy to say, that the original character of the work, and the large amount of information now presented therein for the first time, constitute its principal claims to attention. Amongst the authorities consulted may be mentioned Dr. Boverton Redwood's standard work on "Petroleum and its Products;" the Proceedings of the Institutes of Civil and Mechanical Engineers; the Journals of the Chemical and Geological Societies; the official organs of the Baku Association of Naphtha Producers; the Baku newspaper press; the English journals *Petroleum*, *Petroleum Review*, *Engineer*, *Engineering*, and *Compressed Air*, as well as daily papers; Marvin's "Region of the Eternal Fire;" the excellent articles in the "Encyclopædia Britannica," etc., etc.

My personal thanks are due to Mr. David Forbes, late British Vice-Consul at Baku; Mr. Ecklund and Mr. Petersen, of Messrs. Nobel Brothers, who kindly placed at my disposal many valuable documents referring to their investigations; Mr. A. F. Biering, and his colleagues Mr. Petersen and Mr. Seitz; Mr. Bepple, of Bepple Brothers; the late Mr. Wagstaff; numerous Russian engineers in Baku; and to my many valued English friends in Russia, for willingly supplying me with information on special subjects as well as rendering other services. I must also extend my thanks to Mr. Gulishambaroff, Attaché to the Ministry of Finance, for permission to use any of his publications, and to other Russian officials who so courteously supplied information whenever it was sought. To Mr. Poznanski great credit is due for the infinite pains spent in the translation into English of the Russian Rules and Regulations, which it is hoped will prove a valuable Appendix to the volume.

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[*] In the transcription of Russian words I have not confined myself to any fixed system (for instance, Bak*u* and Bat*ou*m are obviously not in accord), but have followed general usage with words of common occurrence, and in other cases have followed as simple a phonetic spelling as possible.

It will be observed in the text that I have not followed custom in the spelling of the word "bale" and its correlatives ("baling" out the oil), but have accepted Dr. Murray's explanation of "bail" as the proper form.

Many of the photographs reproduced in the work were taken by myself specially for the purpose, but I am gratefully indebted to Messrs. Biering and Ralph, Mr. Shushin, and Mr. George, for permission to reproduce various photographs of theirs, as well as to the publishers of *Petroleum* for the loan of several blocks. It is right that I should acknowledge the painstaking and skilful assistance rendered by the engravers, Messrs. Bursill and Ladyman, in the matter of illustrations. They have been particularly successful in dealing with photographs from which I hardly expected good results.

I owe a considerable debt of gratitude to my father—Mr. Beeby Thompson, F.C.S., F.G.S., of Northampton—for reading over the proofs, and for his assistance in the geological and chemical observations; to my brothers—Mr. G. H. Thompson and Mr. F. W. Thompson—for carefully preparing plans under my supervision; and to my friend, Mr. F. C. Thompson, also of Northampton, for many valuable suggestions made during the progress of the work. Special credit is due to him for the great care expended in the preparation of the photo-micrographs of the foraminifera and oil sands, and for photographing the illustrated geological specimens. I have also to thank my father and Mr. F. C. Thompson for going to considerable trouble in the laboratory over many scientific points on which I felt much difficulty, and the determination of which has a material bearing on the problem of the origin of petroleum. I must also express my appreciation of the services rendered by my partner, Mr. Campbell M. Hunter, B.A., A.M.I.C.E., who, besides critically reading through the proofs, voluntarily undertook the tedious duty of checking the calculations and verifying my figures. Finally, it would not be fair to refrain from acknowledging the help given me in this first literary effort by my wife, who has throughout the progress of the work displayed the keenest interest in its production, and devotedly extended her assistance, not only in translations, but in kindly criticisms by which I have endeavoured to profit.

A. BEEBY THOMPSON.

LEADENHALL BUILDINGS,
1, LEADENHALL STREET, LONDON.
March, 1904.

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CHAPTER I.

INTRODUCTORY.

Historical.—The natural gas exudations and the petroleum deposits of the Apsheron Peninsula have been known for many centuries; indeed, it is asserted that the existing site of the Temple of Fire-worshippers, situated near the extremity of the peninsula, at Surakhany, has been frequented by Parsee devotees for more than 2500 years, and, according to the statement of the British Consul at Batoum, the last priest only departed a few years ago. It is also affirmed by historians that the Baku petroleum has for centuries been collected by the Persians and sent into the interior of Persia and India, where the white variety, found in some districts, was employed as a medicine for curing divers internal complaints, or applied externally as a dressing for relieving irritant sores, etc.; but there is little evidence to show that the common "crude" was used as an illuminant or a source of heat, except in the form of briquettes made by mixing the oil with ashes or earth. In 1723 Baku was annexed by Peter the Great, but in 1735 the territory was restored to Persia, being eventually re-occupied by Russia in 1806.

When Russia took possession of Baku a second time there was a small trade in oil, and the Government, after deliberation, granted to a merchant named Meerzoeff a monopoly for extracting oil from the petroleum deposits, in return for payment of a royalty on all oil raised, the effect of which was to restrict the output of petroleum, which, in 1872, only amounted to about 1,500,000 poods per annum. A popular demand for the abolition of the monopoly arose, to which the Government ultimately assented (1872), but its removal was followed by the imposition of a tax in the form of excise duty. The oil industry showed a marked improvement under the altered conditions, although still impeded from full development, but in 1877 the excise duty was also cancelled, and the business, freed from all restrictions, rapidly increased in magnitude and importance.

Previous to the year 1871 all the Russian petroleum was obtained from hand-dug surface pits, the deepest of which rarely exceeded 50 feet; but in the year named the first oil well was bored on the Balakhany plateau, and the highly successful results attained opened up a new era in the oil fields, by the appearance of fountains, or what the Americans term "gushers." The common occurrence of fountains which followed the introduction of the drill totally demoralized the Baku petroleum industry for a time, and the price of crude oil fell to about one-eighth of its former cost on the striking of the first "gushing" well. The tapping of deeper oil strata, which it had been impossible to reach by hand-dug wells, resulted in the outrush of petroleum in quantities hitherto unprecedented in the world's history, and the verity of the reports which reached England and America concerning the Baku "gushers" was for many years doubted, if not disbelieved.

The Brothers Nobel, two engineers of Swedish extraction, who were destined to revolutionize the whole oil industry of Russia, opened a small refinery at Baku in 1875, where they employed their undoubted talents in building up a modern refining plant by introducing a number of Western ideas. Robert and Ludwig Nobel were far-sighted enough to see the possibilities that lay in the petroleum industry, and they not only exerted their remarkable commercial abilities in the operations of producing and refining, but they took the necessary steps to secure a market for their goods in the Russian centres—a point which had till then been quite neglected by the Baku refiners. In a few years the Brothers Nobel, with the assistance of money already in the family, laid the foundation of an enterprise that eventually became one of the greatest industrial concerns in Europe, and they were for a time refining and distributing about one-half of the total production of oil from the Baku fields. The Nobels were not only the most modern explorers when they entered the exploiting business, and the most scientific refiners; but they laid down the pioneer pipe-line, at a cost of about £10,000, between the oil fields and Blacktown (the refining suburb of Baku), for the delivery of crude to the refineries; they built the first tank-vessel to convey oil in bulk on the Caspian, and constructed the first tank-waggon for the conveyance of oil in bulk on the Russian railways. Table I. shows the increase in production at different periods of the development of the industry, and gives the production of crude petroleum extracted, in poods per annum, from 1863 to 1902.

During the early life of the industry there were few facilities for disposing of the refined products when produced, and whilst America was supplying the Russian demand for kerosene, and conducting a most lucrative business, Baku was shut almost entirely out of the market by the absence of means of transport into the interior and communication with a tidal port. There was no railway connection with Baku, and the owners of vessels trading on the Caspian Sea demanded an unreasonable freight for the transport of dirty kerosene on their vessels to the mouth of the Volga and to Persian ports. The cost of making barrels in Baku, to contain the oils, was very great, the barrel being far more valuable than its contents, and, by the time the refined products reached the Northern and Central Russian towns, the cost often exceeded the value of the American article, although the latter had been conveyed 4000 miles further than the Baku product.

For many years the crude oil from Balakhany was conveyed to the refineries at Blacktown, eight miles away, in barrels supported on Tartar two-wheeled carts, termed "arbars," and the road (the term "road" is used, but the track was, until 1899, unworthy of such a designation) between the two places contained one long string of these carts during the whole day. Nobels' pipe-line, the first one laid in Baku, met with considerable opposition from the carters who formerly carried the petroleum, and it was necessary for a long time to keep guards stationed at frequent intervals along its length to prevent the tubes being damaged by the enraged Tartar cartmen. Other firms, who were very sceptical at Nobels' venture, and declined to take part in such a scheme when invited, quickly followed their example on observing the success of the undertaking, and for many years the whole of the oil has reached the refineries in pipe-lines.

TABLE I.

ANNUAL PRODUCTION OF CRUDE PETROLEUM IN POODS FROM 1863.

(Accurate from 1891.)

Year.	Production.	Year.	Production.
1863	310,000	1885	115,000,000
1864	539,400	1886	123,000,000
1865	551,800	1887	160,000,000
1866	688,200	1888	182,000,000
1867	998,200	1889	192,000,000
1868	737,800	1890	226,000,000
1869	1,680,200	1891	274,000,000
1870	1,413,600	1892	286,500,000
1871	1,407,400	1893	324,763,000
1872	1,537,600	1894	297,551,000
1873	4,030,000	1895	377,427,000
1874	4,960,000	1896	386,265,000
1875	5,890,000	1897	422,461,000
1876	12,090,000	1898	485,943,000
1877	15,500,000	1899	525.247,000
1878	20,646,000	1900	600,764,000
1879	23.560,000	1901	671,276,000
1880	24,800,000	1902	636,529,000
1881	40,920,000	1903	
1882	51,646,000	1904	
1883	59,800,000	1905	
1884	89,000,000	1906	

Nobel met with obstruction in every quarter, and after making in vain many overtures to shipowners and trading companies to convey his produce at a moderate rate to the northern Caspian ports, he decided to design and construct a vessel provided with tanks which would convey the oil in bulk to the mouth of the Volga, barges being built for the transhipment and conveyance of the oil up the river. In 1879 the first tank-steamer was constructed, which met with sufficient success to decide the firm to build several more, and from this experiment originated the enormous distributing business which gradually increased and encircled all the principal Central Russian towns.

Russian capital in the petroleum business was confined, until a year or two ago, exclusively to one or two concerns, and the oil industry had drifted into the hands of Armenians and Tartars, who became the proprietors or lessees of nearly all the available oil lands, and owners of most of the refineries. Grants of oil-bearing territory made to generals and officers who had distinguished themselves in the conquests of the Caucasian regions were generally disposed of by the owners for sums that were absurdly small for such valuable holdings, and many Armenian and Tartar inhabitants who purchased lands at that period are millionaires to-day, and many more who can with difficulty write their names are immensely wealthy.

The opening of the Baku-Batoum Railway for general traffic was an event of the greatest importance to the Russian oil industry, for it ensured an outlet for oil in a new region, and, what was most important, it permitted the transport to a tidal port where the petroleum products could be sold to other nations, and an export trade created.

Until about the year 1870 the residuum (locally known by the name of "astatki," which means refuse) obtained, after abstracting the kerosene and other volatile products of any commercial value from the crude petroleum, was a useless article, which accumulated at the refineries, and had to be periodically disposed of by burning in open pits excavated for the purpose; but about this time experiments were independently conducted by several persons with a view to discovering a means of using this residue for firing boilers, instead of wood or coal, which had hitherto always been employed. Difficulties were encountered in the early stages of its career, and many objections were raised to its use; but it may be said to have had its future assured when it was discovered that the astatki could be pulverized by means of a jet of steam and converted into a highly combustible state. Great stress was laid by the opposers of the new liquid fuel on the danger of carrying a considerable amount of highly inflammable fuel in steamers and trains; but it can easily be found, by a practical experiment, that astatki cannot be readily fired, and that a lighted match or splinter of wood is immediately extinguished when plunged into a tank of such fuel. All the objections were proved to be fallacious, and astatki was gradually introduced into the steamers on the Caspian, where it was found to give a much higher evaporative efficiency than wood or coal, and to possess such advantages that the Government, in 1874, adopted it for all the vessels of the Caspian Fleet. Its use extended to the railways, where it was found of inestimable value in the districts where fuel was both scarce and expensive; and, indeed, nearly all over Russia its cheapness assured a ready sale, which soon received the attention of manufacturers and all steam-users who had to pay dearly for wood or English coal (for the coal-fields of Russia are practically undisturbed) for generating their steam.

In 1883 the Baku oil merchants, who were for the most part men of local extraction and very narrow-minded, received a rude shock when the firm of Rothschild commenced to interest itself in local affairs, and reports were circulated broadcast that the firm intended to monopolize the Baku petroleum industry. The house of Rothschild had, previously to this date, secured interests in the oil business under the name of the Russian Standard Co., and were exploiting oil-bearing territory in the Kuban district; but their Baku enterprise was initiated with the object of exporting oil from Batoum to other countries where they held distributing interests. The name of Rothschild carries with it, in many places, the idea of swallowing all small concerns; but there seems little doubt that the presence of this firm, with a plentiful supply of ready money, greatly assisted the Baku refiners, who were paid in advance for their refined products at remunerative prices, and enabled to work when the condition of the industry was far from satisfactory. Rothschilds' companies, in combination with English capitalists, made the first exportations of Russian oil on an extensive scale, thus securing a new and larger outlet for the Baku merchants, and advertising imposingly the peculiar qualities of the Russian kerosenes to the world.

The first Englishman to interest himself practically in the exploitation of Russian oil was Mr. Alfred Suart, who, in the year 1896, floated the European Petroleum Co., after very much difficulty in getting Britishers to invest in Russian oil, with a capital of one million sterling; but properties in Galicia and Roumania, and a fleet of tank-steamers, were included in the purchase. On the now famous Ackverdoff property (No. 977) Mr. Suart sank the first boring in Grosny, which yielded many million poods of oil, and caused endless claims for compensation on account of the uncontrollable stream of oil which broke away, resisting all attempts to staunch its flow, and flooding neighbouring habitations.

The European Petroleum Co.'s Baku properties were purchased from Mr. Zatouroff; but afterwards the leasehold plots belonging to Mr. De Boer were also bought and added to the company's lands. This company was followed, in 1897, by the flotation of the Russian Petroleum and Liquid Fuel Co., formed with the object of acquiring the famous Tagieff property (plot xix.) at Bibi-Eibat, upon which one well alone, immediately after the completion of the transfer, gave 30,000,000 poods in a month, equal in value to about half the purchase price of the plot. The Baku-Russian Petroleum Co. and the Schibaieff Co. were the next to appear (1898), which bought respectively the properties and refineries of Mr. Arafeloff and Mr. S. M. Schibaieff, the latter proprietor having a far-famed name for lubricating oils. During the last few years (to 1902) a number of smaller English companies have been formed for the purpose of exploiting oil lands in the Caucasus, a list of which appears in another place.

The effect of English capital has been to stimulate and inspire energy into the industry; and, far from financiers taking money from the country, they have invested more than £6,500,000 in Russian oil, a great deal of which will never be recovered, and it is doubtful whether more than a small proportion will ever pay a profitable return, on account of the high prices paid for partially exhausted grounds. English companies have been the medium through which many innovations of British and American extraction have been introduced into the oil fields, and many thousands of pounds have been expended by them in testing new plant and appliances connected with the exploitation and extraction of petroleum. With the exception of Nobels and a few other Baku companies, proprietors opposed on principle any innovation of whatever value, and could only with the greatest difficulty be constrained to adopt a modification of their old methods, so that the presence of English engineers on the oil properties cannot fail to have given to the local employees many Western ideas. The enforcement of the law making it compulsory for each oil property to be managed by a trained Russian engineer, will no doubt lead to great improvements in the general conduct of the business, and cause a large body of engineers to make a specialty of the petroleum branch, most important for Russia's further exploration of oil territories.

Until about the year 1895 the extraction of kerosene and a few other oils was the chief aim of refiners, and the astatki was looked upon as a waste product, and, as such, fetched a low price when placed on the market, so that manufacturers, railway companies, and steamship owners were, till this time, presented almost gratuitously with fuel by the Baku producers at the expense of burners of kerosene. The unconsciousness of the value of the gift of residuals to all who cared to avail themselves of it was not without its reward to the donors, for its cheapness served to popularize and familiarize liquid fuel over a large area, and cause thousands of manufacturers to erect their industrial plants in the Volga districts, and employ only astatki as fuel. The result of the enormous demand thus created caused the price of astatki to slowly rise, until at times it exceeded in value the cost of kerosene and even crude oil; as, for instance, in March, 1901, when crude petroleum was 10·5 copecks, kerosene in ships 9·25, and astatki 13 copecks per pood; and in June, 1898, crude was 9 copecks, kerosene 10·75, and astatki 10 copecks a pood; so that at times a waste product actually exceeded in value the refined article.

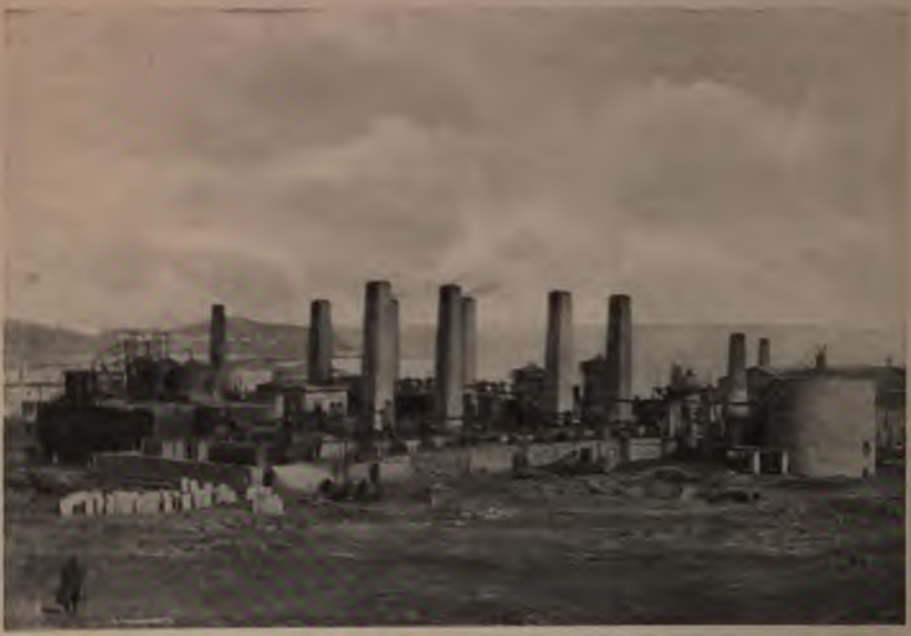

Fig. 1.—Typical Blacktown Refinery.

During the period that kerosene was the object of refining, the lighter crude oils were in demand, and exploiters sought those which contained a large percentage of the volatile hydrocarbons, avoiding the heavier classes; but as soon as astatki became the article that refiners worked for, the heavier oils were at a premium, and fetched in the market a quarter to a half copeck per pood more than the lighter. There is a considerable difference in the composition of petroleum from different districts, and even from various sections of the same oil field; the proportion of benzine, kerosene, and heavy hydrocarbons that can be converted into lubricating oils exhibiting a wide range. The Balakhany district yields the heaviest and the richest oils containing hydrocarbons for lubricating oils, with a small percentage of benzine, whilst Bibi-Eibat and Grosny petroleums contain a much larger percentage of benzine and kerosene, which depreciates their value for the formation of residuum. The relative values of the oils extracted from different districts will be seen from the following tabulated particulars, taken from Redwood's treatise on Petroleum:—

Product.	Balakhany-Saboontchy.	Bibi-Eibat.	Grosny.
Specific gravity . .	0·865 to 0·870	0·855 to 0·858	0·884
Benzine . . .	5 „ 6%	10·5%	20%
Kerosene . . .	27 „ 33%	40 %	20%
Solar oil . . .	5 „ 6%	13·5%	—
Residue . . .	50 „ 60%	36 %	50%

Uses of Petroleum and its Products.—It would not, perhaps, be out of place to mention here a few of the commercial uses of petroleum and its products, which have, during the last few years, assisted materially in increasing the demand for such goods, and which will undoubtedly be greatly augmented during the next year or two. Crude Russian petroleum, as it is raised from the earth, is a dark-brown or greenish, viscous material composed essentially of hydrocarbons, the exact composition of which varies much in different districts; but all crude petroleum is capable of parting with a proportion of its constituents when exposed to an increase of temperature, and even under normal atmospheric conditions volatile gases are evolved in small quantities. When heat is applied the lighter hydrocarbons, which are only liquid at low temperatures, are driven off, and if these are condensed in a cooling chamber leading from a retort in which the heating is conducted, the first product will be found to be a white, highly volatile explosive liquid termed *benzine,* which needs great care in its manipulation and storage. On the application of an increased temperature a more stable fluid may be condensed in the cooling-vessel, that is much safer to handle, and goes by the name of *kerosene* under which designation it is used all over Europe for lighting and heating purposes, after passing official tests for specific gravity and flashing point. Sometimes a third distillate is condensed, termed *solar oil,* which is merely a less valuable form of kerosene, its use being generally confined to commercial processes, after which remains a heavy viscous residue which constitutes the Russian *astatki,* or the now well-known liquid fuel.

An excellent condensed description of the continuous system of distillation, first introduced by the Nobels, is given in the latest edition of the "Encyclopædia Britannica," the purport of which is as follows: In the continuous system of distillation, instead of a single still with a progressive temperature, there is a series of retorts heated to successively higher temperatures, which are carefully maintained, and the crude oil is caused to flow slowly and continuously through the whole series, being thus subjected to a steadily increasing heat, whilst the contents of each still remain practically constant. In this manner each still yields continuously a product of given volatility, corresponding with the temperature at which it is maintained, and from the series of stills a range of products is continuously obtained, corresponding with that yielded by the intermittent system within the same limits of temperature. In this system the loss of time, waste of fuel, and injury to plant involved in the cooling down and reheating the stills are avoided.

From some classes of oil the residuum is treated by special processes, and viscous or solid compounds are formed which pass under the name of *lubricating oils*, *vaselines*, and *paraffins*; but this is a distinct branch of refining, and necessitates the treatment of the residues in a very scientific manner. The kerosene so condensed has to be cleaned, clarified, and freed from injurious compounds by agitation with sulphuric acid and sodium sulphate before it is ready for commercial purposes. The benzine formerly had no sale, and was used as fuel in the refineries, and even run into the sea; but to-day various qualities of benzine are extensively used in the arts, in the manufacture of rubber goods, etc.; but it also has a large application, under various names, for employment with small motors on launches and motor-cars, besides many bigger engines, known as benzine-motors, manufactured by English, American, and German firms. Benzine possesses powerful detergent qualities, and is ordered in large quantities for the purpose of cleaning clothes, household goods, and removing grease stains from articles, and it finds a ready sale for burning in small spirit-lamps, and some varieties of plumbers' lamps where great heat is required.

The chief use of kerosene is for lighting purposes in all districts where coal-gas or electricity is not available, and it will be quite understood that the demand for this illuminant is especially great in the immense Russian Empire, where few towns are lighted by gas, and where thousands of square miles are populated by a poor peasant class. In England and all European countries, kerosene is still the sole material for lighting the village streets and inhabitants' houses in rural districts, but until a few years ago its employment as an illuminant had enormously decreased in large cities, and was being entirely replaced by cheap gas and penny-in-the-slot machines placed in the poorer quarters, and by electricity in the wealthy and commercial districts. The incandescent oil-lamp revives the appearance of the old-fashioned lamp, and there are not only examples of extensive public services being installed, but electric lamps have actually been replaced by the newly invented oil-lamp, in some instances with satisfactory results. The Kitson lamp is, perhaps, the most successful type yet patented, and consists of an air-pump for supplying air at a pressure to force the oil to the burner, and a device by which the heat emitted from the lamp vaporizes the kerosene, the generated gas being mixed with the necessary quantity of air by a controlling arrangement, and burnt beneath an incandescent mantle in the manner of a Bunsen burner. The light derived from the incandescent oil-lamp exceeds in luminosity that secured from either electricity or incandescent gas; and as the peculiar penetrative power that characterizes an oil-light (due, as investigation shows, to richness in rays belonging to the red end of the spectrum), which has been always valued so much for lighthouse work, is said to be retained in this new method of burning oil, a large new field of operation lies before it. The

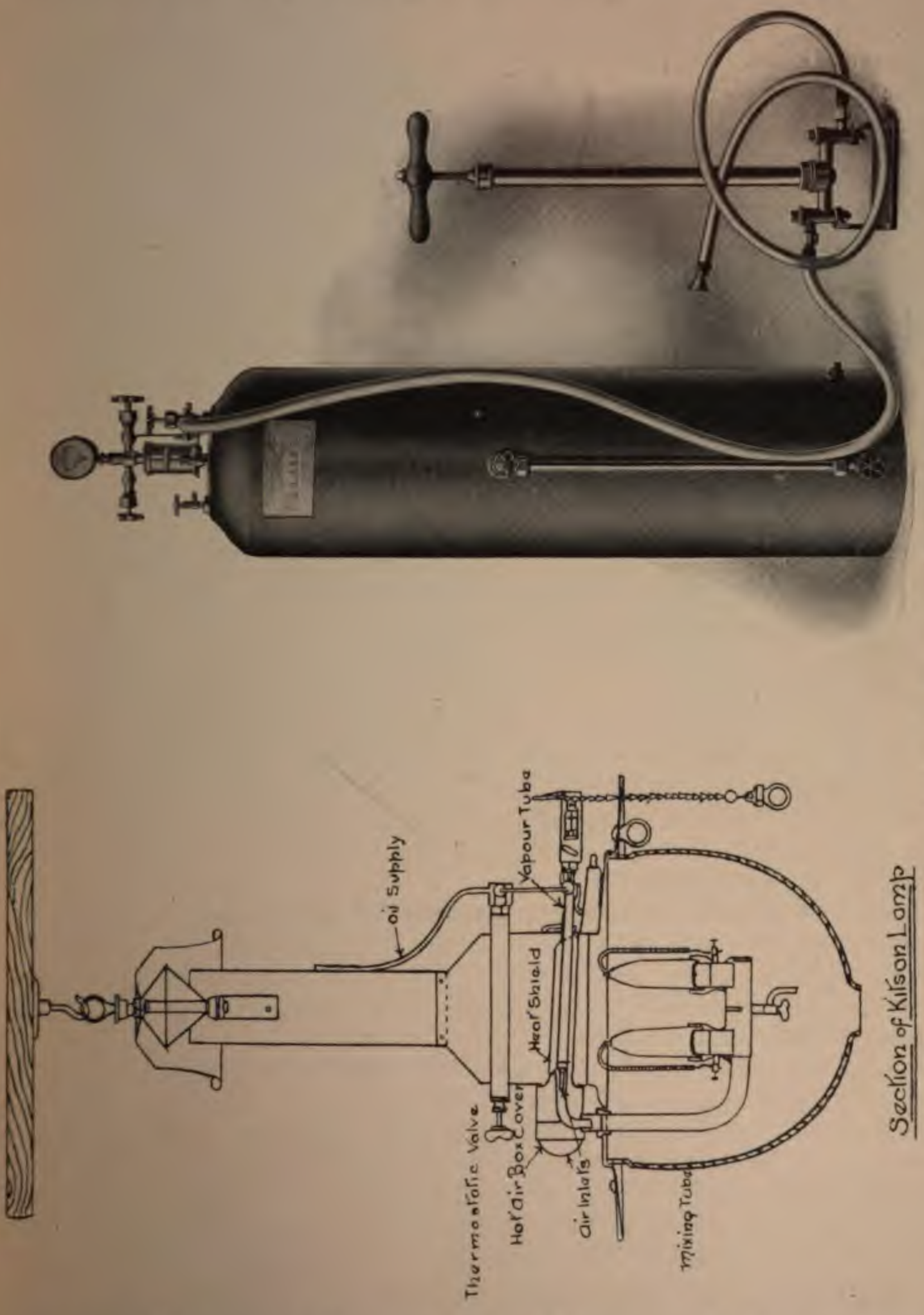

Fig. 2.—Latest type of Kitson Incandescent Oil-Lamp.

cost per candle-power, at the present price of kerosene, with the incandescent oil-lamp, is reported to be considerably less than electricity or gas-lighting, and the owners of the patent have claimed to be able to give nearly double the ordinary light in busy thoroughfares for about one-half the price paid for gas or electricity. The Whitehall experiment, and the result of the decision of the Trinity House officials to erect these lamps in a number of important lighthouses, will be curiously observed, and if the new lighting fulfils all the declarations of the patentee, a large extension of their use may be expected.

COMPARATIVE COST OF LIGHTING BY DIFFERENT METHODS.*

(Cost per 1000 candles per hour.)

	s.	*d.*
Electricity, 3½*d.* per unit—		
Incandescent lamp	1	2
Arc lamp	0	3¾
Coal-gas, 16 candle-power, at 3*s.* per 1000 cubic feet—		
Flat flames	1	6
Argand burner.	1	0
Incandescent burner.	0	2¼
,, pressure burner	0	1¾
Oil—		
Duplex lamp, oil at 8*d.* per gallon	0	7¼
Oil-gas lamp, oil at 4*d.* per gallon	0	6
Incandescent lamp, oil at 8*d.* per gallon . . .	0	2¼
,, air-gas lamp, gasolene at 10*d.* per gallon	0	2
,, lamp, Kitson system	0	1

Another use of kerosene on a large scale is for heating-stoves and cooking-ranges, which have reached a high state of perfection, and come largely to the foreground since the advent of this cheap illuminating and heating agent, and which confer such a blessing upon the thrifty householder who cannot afford to burn a coal fire all day.†

Kerosene engines are now largely advertised which generate a unit of power at an extremely low cost, and work without the assistance of a regular attendant, being simple, safe, self-oiling, and reliable; and in Russia there is a special demand for this class of motor far away from railway stations, for agricultural and irrigation work.

Solar oil and kerosene have also been found to be valuable agents for enriching coal-gas, and most large gas companies in England and elsewhere now carburet their coal-gas by the addition of a percentage of vapour derived from one of these liquids. Oil-gas, unadulterated, is found to be a very convenient illuminant for railway carriages, etc., where it is necessary to convey gas in a compressed form, as it suffers much less deterioration by compression than coal-gas. Oil-gas, derived either from crude petroleum, kerosene, or solar oil, has been extensively adopted for the working of gas-engines, where it is found to be a very cheap form of energy wherever the oils can be transported in bulk to their destination.

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* Extracted from the article "Petroleum" in the latest edition of the "Encyclopædia Britannica."

† Fig. 3 illustrates a cooking-range and a heating-stove sold by the Consolidated Petroleum Co., Ltd.

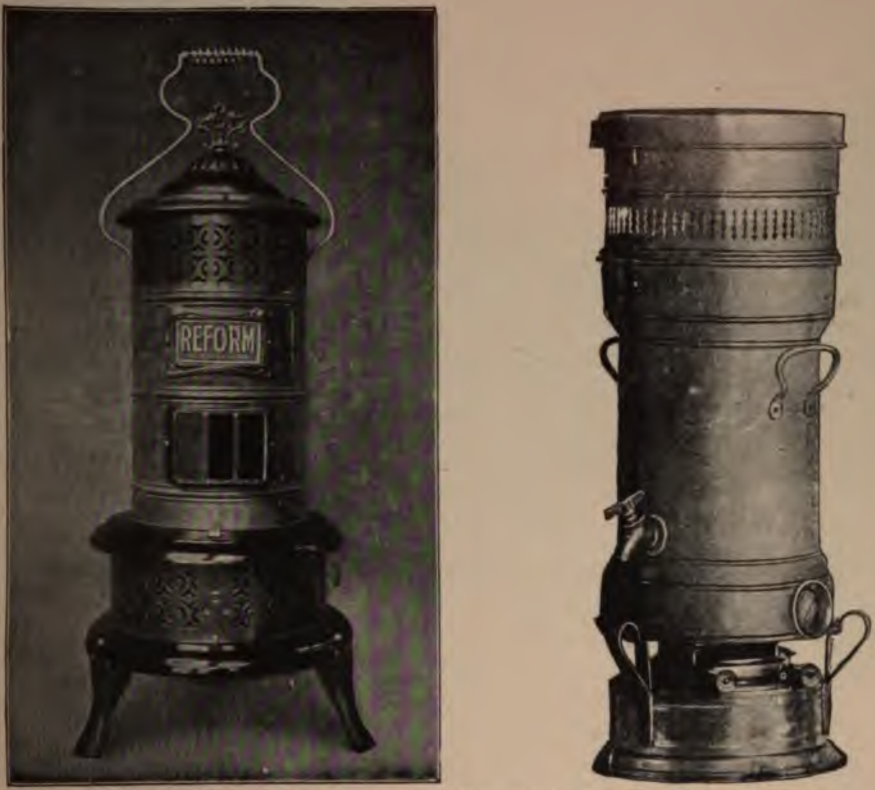

Fig. 3.—Oil Heating and Cooking Stove as sold by the Consolidated Petroleum Co., Ltd.

The residue, after the abstraction of the above oils, forms a most valuable fuel, which generally goes by the name of "liquid fuel," giving out, when burnt, from 30 to 35 per cent. more heat units than a corresponding volume of average coal, and having a 40 to 50 per cent. higher calorific power than an equal weight of average coal.

From some residuals may be produced paraffin wax, and lubricating and purified oils of different qualities, possessing all kinds of widely divergent characters and flashing points, as well as vaselines, greases, etc., etc., so that some idea of the extent of the employment of petroleum and its products in the arts can be realized. The latest reports of malaria research seem to show that petroleum is destined to exterminate the malaria-spreading mosquito which causes the death-rate amongst *picked* white lives in West Africa to reach 30 per cent. per annum in some places; for news from Sierra Leone confirms the expectations of the Liverpool School of Tropical Research that the judicious deposition of a little petroleum on the collections of water prevents the reproduction of the pests.

Table II. gives the total output of the Baku refineries in 1902, and shows the destination of all the various products. Table III. gives the outputs of the four Grosny refineries. Attached is a tabulated list of the principal Baku exporters, and against each is shown the quantity of petroleum products despatched in 1902.

TABLE II.

SHOWING DESTINATION OF ALL BAKU PETROLEUM PRODUCTS IN 1902.

Illuminating oils.	Lubricating oils.			Residue, or astatki.	Crude oil (untreated).	Benzine.	Lubricating oil residuals.	Goudron, asphalt, etc.	Total.
	Engine and cylinder oils.	Solar oil.	Total.						
TOTAL PRODUCTS FROM BAKU REFINERIES.									
120,207,529	13,570,148	744,802	14,314,950	342,546,808	34,070,828	269,712	1,597,474	365,776	513,373,077
TOTAL EXPORTS VIA CASPIAN SEA.									
46,029,170	3,137,094	538,784	3,675,878	336,404,720	21,560,350	155,620	1,523,955	43,035	409,392,728
EXPORTS TO ASTRAKHAN.									
35,592,376	2,821,819	522,476	3,344,295	321,021,132	21,278,383	152,080	1,519,290	38,883	382,946,439
EXPORTS TO PETROVSK.									
8,380,298	301,882	—	301,882	2.246,616	215,622	—	4,665	2,275	11,151,358
EXPORTS TO TRANS-CASPIAN PORTS.									
1,100,473	9,298	1,404	10,697	10,333,509	—	837	—	1,723	11,447,239
EXPORTS TO PERSIA.									
949,335	—	—	130,772	46,712	—	—	—	—	1,126,769
EXPORTS TO OTHER CASPIAN SEA PORTS (LENKORAN, ASTARA, ETC.).									
6,688	4,100	14,904	19,004	2,672,741	19,633	2,703	—	154	2,720,923
TOTAL EXPORTS BY RAILWAYS.*									
73,373,281	10,256,613	176,610	10,433,223	4,685,912	12,471,735	56,224	47,121	113,096	101,180,529
TOTAL EXPORTS BY TRANS-CAUCASIAN RAILWAY.*									
71,044,306	9,621,400	17,903	9,639,303	3,805,134	12,464,376	12,501	17,453	66,863	97,049,936
EXPORTS TO BATOUM.									
69,389,752	9,537,325	12,067	9,549,392	2,170,132	36,764	2,050	11,563	11,276	81,170,929

* Of the 73,373,218 poods of kerosene taken by railway, 58,493,401 poods were pumped though the Trans-Caucasian pipe-line.

EXPORTS TO TRANS-CAUCASUS.

Illuminating oils.	Lubricating oils.			Residue, or astatki.	Crude oil (untreated).	Benzine.	Lubricating oil residuals.	Goudron, asphalt, etc.	Total.
	Engine and cylinder oils.	Solar oil.	Total.						
1,654,554	84,075	5,836	89,911	1,635,002	12,427,612	10,451	5,890	55,587	15,879,007

EXPORTS BY BAKU-PETROVSK SECTION OF VLADIKAVKAS RAILWAY.

2,328,912	635,213	158,707	793,920	880,778	7,359	43,723	29,668	46,233	4,130,598

PRODUCTS USED IN BAKU AND THE PROVINCE OF BAKU.

805,141	176,441	29,408	205,849	1,456,176	38,743	57,868	26,398	209,645	2,799,820

TABLE III.

THE OUTPUTS OF THE FOUR GROSNY REFINERIES.

Name of product.	Refinery of the Vladikavkas Railway Co.	Ackverdoff Refinery.	"Oospek" Refinery.	"Nadejda" Refinery.	Total.
Benzine distillate .	332,490	439,499	73,170	12,621	857,780
Kerosene „ .	777,577	1,426,352	394,871	189,779	2,788,579
Astatki . . .	5,264,903	8,568,542	1,406,344	659,147	15,898,936
Solar oil . .		188,196			188,196
Ligroin . . .	386,121	333,872	91,262	52,772	864,027
Gasoline . .		62,393	168,480	69,058	299,931
Total products .	6,761,091	11,018,854	2,134,127	983,377	20,897,449
Lost in distilling .	523,660	508,173	147,686	44,799	1,224,318
Total . .	7,284,751	11,527,027	2,281,813	1,028,176	22,121,767

CHIEF EXPORTERS OF PETROLEUM PRODUCTS FROM BAKU, WITH QUANTITIES EXPORTED IN 1902.

Name of exporter.	Exports of oil products in poods.
Messrs. Nobel Bros.	113,311,000
Messrs. Mantasheff & Co.	42,989,000
Kerosene and Lubricating Oil Co. . .	40,034,000
Caspian and Black Sea Co.	39,794,000
Caspian Co.	28,581,000
Mazoot Co.	28,240,000
Schibaieff Petroleum Co.	25,171,000
Buniatoff	19,620,000
Eastern Oil Co.	17,913,000
Russian Oil Co.	13,855,000
Assadulaieff	12,099,000
Musa Tagieff	12,043,000
Tumaieff	10,917,000

Terms on which Oil Lands are held in Russia.—The Imperial Russian Government, after the annexation of the Caucasian and Trans-Caucasian provinces, took possession of all the forest and mineral lands, and granted to the peasants of each village rights to utilize the surface pasturage, etc., for agricultural pursuits, but no powers to extract mineral wealth from beneath the surface. Exceptions were allowed to particular individuals and residents of villages to retain perpetually certain grounds, but the Crown Ministers were authorized to purchase from such persons all mineral-bearing grounds, where possible, to which the owners held indisputable rights. Many large tracts of land in the Caucasian provinces were allotted by the Government to the military authorities for distribution to the men composing the Cossack Army, in exchange for their term of military service rendered to the State, but all grants so made entitled the holders only to surface rights, and when mineral wealth is subsequently found to lie beneath such territories, the lands are exchanged for others, and the royalties and fees obtained by the leasing of the areas to capitalists are disposed of by a committee whose object is to distribute the sums collected amongst funds connected with the Cossack Army. The Russian Government has thus become the possessor of most of the mineral wealth of the Caucasus, which it jealously guards, and only permits of prospection and exploitation on the deposit of substantial guarantees to assure the good faith of the promoters, thus giving the Minister of Finance an immense reserve to fall back upon should occasion demand.

The only Russian oil fields of considerable importance at present are the Balakhany-Saboontchy-Romany plateau to the north-east of Baku, the Bibi-Eibat field to the south of Baku, and the Grosny ridge situated about 10 versts to the north-west of the town of Grosny, the two former districts being chiefly Government lands, and the latter belonging almost exclusively to the Cossack Army of the Don. The minor fields in the Taman Peninsula, the Cuban, Daghestan, and Trans-Caucasian provinces, as well as Holy Island, the Isle of Tcheleken, and Trans-Caspian territories, are owned chiefly by the Russian Government, which only allows prospecting on suitable terms, and grants exploitation leases on a royalty basis. Privately owned oil-bearing lands have been worked by the proprietors in many instances, and the owners have amassed large fortunes, but generally the original Tartar and Armenian peasant-proprietors, like the high Government officials who received grants of lands for distinguished services given to the State, have disposed of their lands to capitalists, who have reaped a rich harvest.

The transfers of many freehold (private) oil properties were conducted on the basis of a lump-sum payment and a royalty of 25 per cent. of the output, but other plots were purchased outright by payment at the rate of 10,000 to 50,000 roubles a dessiatine (2·7 acres). Numerous oil-bearing plots are still in dispute, the Government contesting the proprietorship of the ground, but although permission for boring is usually refused on such land, the authorities are sometimes indulgent enough to grant the required permit on the understanding that the exploiters will remove all their belongings, without receiving any compensation, if the claim in a court of law results in judgment for the Crown. Even where legal decisions are given in favour of the Crown, a lenient treatment is usually extended to those in possession, who are permitted to retain possession of the plot on payment of a fair sum and a moderate royalty.

The original leases in the Baku district were granted by the Government either on a small royalty basis or at a yearly rental, the definite amount being fixed by the position of the property in relation to proved ground. The two original Bibi-Eibat plots (Nos. xix. and xx.) were leased by the Government to Messrs. Tagieff and Zubaloff* at a rental of about 100 roubles a year for the first 24 years (equal to 10 roubles per dessiatine, or about 7*s.* 6*d.* per acre per annum), 1000 roubles a year for the second 24 years, and 10,000 roubles a year for the third 24 years, etc., so that the land can be considered for all practical purposes to be freehold until it has been exhausted. The proprietors of both of the above plots were comparatively poor men, who earned a precarious livelihood by extracting and selling crude oil raised from shallow, hand-dug pits on their respective properties, but they are to-day millionaires, and may boast of having been the owners of the most valuable strips of mineral ground, of equal area, probably ever known. Formerly, leases were granted to petitioners on terms demanding a percentage payment or a royalty per pood, but for a number of years the Government has offered annually a batch of plots for public auction, the number, position of plot, and terms upon which bids may be made being duly published in the newspapers. A stipulation is made that a royalty per pood will have to be paid on a minimum output from each dessiatine, after a reasonable stated time has been allowed for the completion of boring work, the minimum production being decided by the Government after consultation with experts who base their estimations on productive properties in the vicinity. To encourage the active exploitation of leased lands, the royalty is generally one which decreases with an augmentation of output: thus, for each million poods of oil produced above a stated quantity, the royalty is reduced, to within fixed limits, by ¼ copeck per pood. Sealed offers for the lands advertised must be deposited by a fixed date, stating the royalty in copecks and fractions of a copeck per pood the person is willing to pay on the produced oil, and be accompanied by a remittance equivalent to a prearranged proportion of the first year's minimum royalty, as a guarantee of the *bonâ fide* nature of the tender, which sum is confiscated in the event of a tender being withdrawn, but returned if the tenderer's offer is not accepted. The Russian Government, in deciding upon the stipulation of a fixed royalty per pood with a minimum sum assured, no doubt wished to see its revenue on a reliable footing, and not so sensitive to commercial market fluctuations, as would be the case were the royalty arranged on the percentage system; but at the same time, the present arrangement has introduced a highly speculative factor into the industry, which is far from satisfactory, and from which the Russian Government has suffered indirectly, if not directly. The tenders submitted at each auction are naturally based upon the prevailing price of crude oil, so that the Government must necessarily be either the loser or gainer by any subsequent rise or fall in prices; in fact, there have been suggestions—although the author considers them very improbable—that the market is purposely depressed previous to Government auctions by influential interested firms.

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* Plot xx. was originally leased to Jakolli and Co., but Zubaloff leased it and prospected it.

In 1900, when the annual auction of Bibi-Eibat plots was announced, the price of oil stood at 16 copecks per pood, and the offers for land in the neighbourhood of rich, proven plots fetched 8, 10, and 12 copecks a pood, with the natural consequence that on the first fall of prices the lessees were forced either to work at a loss, to cease operations entirely and await an improvement, or to petition the Government to relieve them of their plot. It cannot be denied that there are two sides to the complicated question of royalties, for if speculative financiers make preposterous offers for oil-bearing properties, with the undisguised intention of sub-leasing or selling, and prevent cautious merchants from securing lands at a figure which allows of a moderate remuneration, they should scarcely be protected by the State, and should rightly suffer for their indiscretion; but at the same time, an interested Government, which has its revenue to consider, can scarcely stand idle and see its most remunerative industry injured and its leading merchants ruined without extending some assistance. Direct help, by converting the royalty per pood into a percentage royalty, would obviously be a distinct injustice to firms whose moderate tenders were rejected at the annual auction, and when all sides of the subject are viewed, it appears that the Government could not have acted more justly than it has in acceding to requests for the cancelling of the leases when petitioned by the lessees.

There are other points connected with the leasing of Government oil lands which have recently been prominently brought forward by the natural evolution of the business, one of the most important being the subject of fuel. The fuel consumption (in proportion to the output) naturally varies with the richness of the plot, but, on an aggregate, it amounts to about 10 per cent. of the production, and it has been the practice to allow lessees of Government plots to have their fuel free, *i.e.*, without paying any royalty thereon, so that on an average property a leaseholder is freed from paying a royalty on 10 per cent. of his output. This practice, it is rightly argued, discourages the institution of economizing contrivances, and leads to a great waste of fuel, and, since the advent of electrical energy on the oil fields for bailing and boring purposes, it acts as a retarding influence to its employment. Every one agrees that the absence of boiler-houses on an oil property is a decided improvement and a desirable innovation, and that electrical power, if reliable, is a great boon; but it is scarcely the policy of the Government to subsidize the electric-power companies, as would happen in most cases if the authorities acquiesced in the popular request to allow 8 or 10 per cent. of the produced oil to be given free of royalty on properties utilizing electrical energy. A committee which considered the proposition recommended an allowance of 8 per cent. for Bibi-Eibat, 9 per cent. for Saboontchy and Romany, and 12 per cent. for Balakhany.

The sizes of separate plots in the Baku region vary from 1 to 10 dessiatines, the larger portion being under 2 dessiatines in extent; but the Government refuses to grant boring rights to holders of less than 1 dessiatine, except in special cases, and such small properties can only be exploited by combining with adjoining proprietors or lessees. In the Grosny oil district the plots are generally divided into 10-dessiatine blocks, and leased out for a period of 24 years, by the officials administering the estates of the Cossack

Army, at a royalty of 1 copeck per pood for the first two millions, and ½ copeck per pood on each successive million poods; but the administrators reserve the right to modify the terms of the agreement after 12 years, and the lessees are bound to agree or retire. In the outlying, unproven parts of the Grosny territory the ground is divided into huge plots, which may be explored by prospectors on a deposit of suitable guarantees with the authorities; and in the event of oil being struck, the explorers may choose 10 dessiatines, on which they are entitled to conduct exploitation. There are enormous tracts of known oil-bearing territory which the Government will not yet allow to be exploited, the Ministers remembering, no doubt, the wanton waste of petroleum which occurred in the early period of the Balakhany field, when the cheapest mode of disposing of millions of poods of oil was by burning.

Association of Naphtha Producers.—Local rules and regulations for the administration of the oil fields, conduct of the work, and protection of the producers' interests, are drawn up by a committee of leading persons connected with the industry, in conjunction with certain Government officials, determined according to the laws cited in Appendix B. The committees so formed at each large oil centre go by the name of Associations of Naphtha Producers, and constitute councils similar to town councils in England, armed with powers to assign a tax for the proper laying out of the oil fields and improvement of the district wherein the wells are distributed. The tax is a charge levied on every pood of oil delivered from the properties, and the funds are employed by the association for the construction, maintenance, and lighting of roads, the drainage of the oil fields, the maintenance of free hospitals for sick and injured workmen, and the up-keep of branch ambulance stations for the treatment of minor accidents and ailments, the formation of a fire-brigade, the purchase and distribution of fire-extinguishing appliances, etc. The association also appoints a technical committee to study special technical problems which are from time to time brought forward, relating to the oil industry, and is authorized to appoint extraordinary commissions to investigate and report upon subjects which are of considerable importance to the business, or necessary for the safety of the wells. The Baku Association of Naphtha Producers is one of great importance, for as Baku is the centre of the chief oil-producing region in Russia, and one of the largest sources of revenue to the State, the results of its deliberations and subsequent recommendations go a long way towards influencing the high State officials in their future dealings with oil lands.

The Baku Association has a properly organized statistical bureau, where figures and data relating to the oil industry are carefully compiled and tabulated, and published annually in the form of a review, and fortnightly in a journal conducted under the directions of the association by a competent staff. The local statistics are prepared from information supplied by all the companies operating in the district, on special printed forms circulated for the purpose, which must be filled up with all the required details and be despatched to the office of the committee. The fortnightly journal, *Neftiano Delo* ("Oil Business"), not only contains a full account of the meetings of the Association of Naphtha Producers, and reports of the sub-committees and commissions, but it is posted up with all the latest information relating to other oil centres, gives a description of the shipments and distribution of oils in all parts of the world, and contains articles on interesting subjects connected with the trade.

The local tax in the Baku district has steadily risen, and it now stands at one-tenth ($\frac{1}{10}$) of a copeck per pood on all oil delivered from the properties, realizing a revenue of about 600,000 roubles a year. In Grosny the tax is now fixed at $\frac{1}{15}$ copeck per pood, and realizes about 20,000 roubles a year.

Five years ago there was scarcely a track in the whole of the Baku oil fields worthy of the title of a road, and on the first appearance of rain, transport of all materials to the wells was stopped, and light traffic could only be continued with the greatest difficulty, whilst movements on foot had to be made knee-deep in filth and slush. Everything has since been altered, and besides a properly macadamized road constructed from Baku to the wells for the conveyance of goods, in place of a muddy plain over which carts struggled as best they could, there are many cross-roads by which access may be gained to the various clusters of properties. The number of roads in Bibi-Eibat and Balakhany is still far too few, and the type of construction, namely, the bedding of whole flints in a base of sand, is not one conducive to easy traffic; but improvements are daily taking place, and the exertions of the committee have entirely altered the condition of the Baku oil fields during the last four years. The traffic connected with the exploitation of oil is of a very heavy description, and special facilities should exist for the rapid and cheap movement of goods; but although schemes have been prepared for the encircling of the oil fields by a railway, the projects have never matured. If stoned roads are to be retained for the service of goods in the oil-well districts, it is to be highly recommended that the whole-flint and block-granite processes be abolished, and that the ordinary crushed-granite or broken-flint roads be entirely used, for the damage sustained to the springs of vehicles of all classes, as a result of the violent vibration on the uneven cobbles, is enormous, and is the immediate cause of a startlingly heavy annual account to all companies for repairs to phaetons and transport-carts.

The railway which has for many years connected Baku with the Balakhany-Saboontchy oil field—upon which some old Sheffield engines are still running—was, in 1900, enlarged from a single line to a double one, in order to improve the daily service of trains, which was quite inadequate before the change; but in Grosny, the oil fields, although situated 10 versts from the town, are connected by neither a railway nor a road with Grosny or the main railway line. A stranger visiting Grosny for the first time at once remarks on the total absence of all transport arrangements with the oil wells, whilst the topographical nature of the ground is peculiarly adapted to the cheap construction of roads, being level the whole distance. The track to the wells traverses a plain covered with soft alluvial soil, which, in wet weather—and Grosny is a very wet district—allows the wheels of every heavy vehicle to sink deep down, making it impossible for a second cart to pass in the track of a preceding one, and rendering the carting of all materials impossible except when fine weather prevails. The result is that each cart gets as far away from the original road as possible, and a sodden, muddy mass, nearly 500 yards wide, extends from the town of Grosny to the wells, where dozens of struggling horses may be seen dragging with difficulty a load that one cart-horse would move easily on a macadamized road. A level valley flanges the whole length of the ridge upon which the productive properties lie, and a light railway covering this distance would bring the oil fields within half an hour of the town, and reduce the cost of transport to a fraction of its present cost. Some idea of the difficulties of conveying goods over these few miles can be gained when it is said that 800 roubles (80 guineas) have been paid to a carter to get a steam boiler removed from Grosny to one of the properties—a work necessitating the employment of a hundred pairs of oxen. Private enterprise in matters of railway communication is discouraged by the Government, and the railway administration procrastinates to such an extent that there is little prospect of a direct line between Grosny and the wells being established within a reasonable time, unless the naphtha producers are themselves willing to expend the necessary sum for the construction of a road, —an expensive undertaking for a small producing centre, and one that would be very reluctantly carried out in the present depressed state of the market.

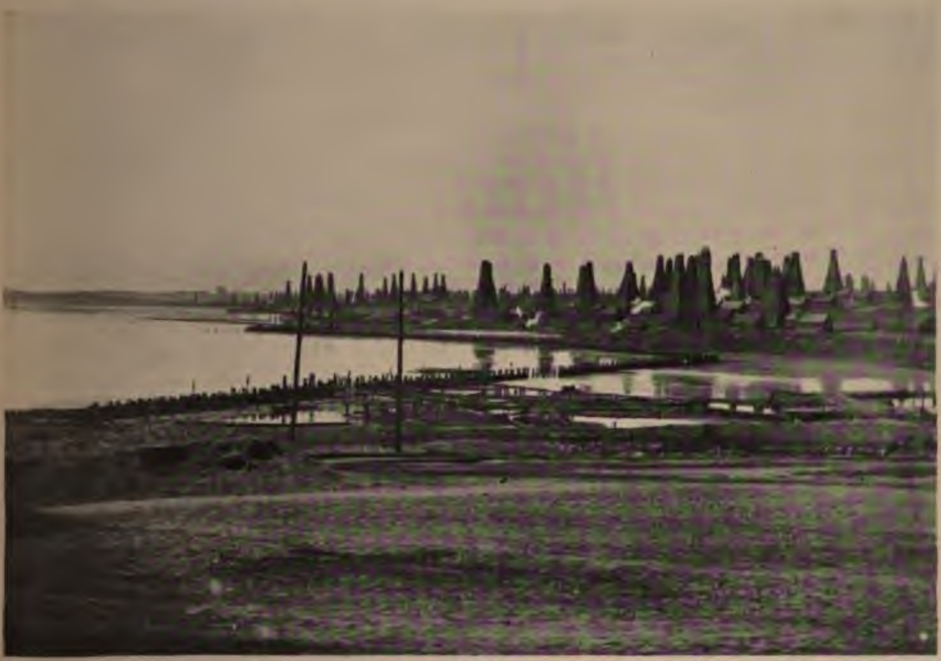

Fig. 4.—The Romany Lake, which is about to be reclaimed.

(View from the Romany side.)

One very important work conducted by the Association of Naphtha Producers at Baku was the drainage of the Balakhany-Saboontchy oil field at a time when the disposal of the water removed from the oil wells was assuming a serious phase, and threatening to become a nuisance to the district. Owners of oil properties were forced to dispose of their water in any way that was possible, and as the oil field is situated on a plateau surrounded by a ridge of limestone hills, all depressions in the ground were soon converted into saline lakes by the accumulation of waste water, and large areas rendered impassable and valueless. The Romany lake is most conveniently situated for receiving the drainage of a large area, and, notwithstanding repeated requests to owners of properties near the lake to pump their waste into the main canal, the dimensions of the lake are annually increased, and the water has already flooded some oil properties and low-lying parts of the village of Saboontchy. A system of canals is arranged, traversing the districts along the contours of the ground; and these converge at certain points, and lead to a main channel that passes through the ridge by a tunnel (near the Saboontchy Railway Station), and conducts the water to a position outside the field, the waste oil being collected by a contractor, who obtains the right by payment of a sum of money to the authorities. A small station, fitted with centrifugal pumps, gives the means of lifting the water to a sufficient height to allow the stream to flow by gravitation through an open conduit direct to the Caspian Sea. Centrifugal pumps of a similar type raise the water which collects near the Saboontchy Station, and discharge it into the canal near the tunnel; and from the total discharge of waste water, about a million poods of oil are annually obtained. Recently a modification of the gradient and the construction of a deeper conduit have enabled the waste water to run away by gravitation, without the interception of the outer pumping station, and in another year or two a tunnel leading from the lowest portion of the Romany lake will permit the whole oil field to be drained without the assistance of any pumping machinery. The Bibi-Eibat field is much more conveniently situated than the Saboontchy region, as the distance from Baku is only about 3 miles, instead of 8 miles, and the Caspian Sea is handy for the disposal of waste water.

Means of disposing of Crude Oil from the Properties.—Petroleum bailed from the wells is usually allowed to stand for a time in a spacious underground tank, where the suspended water and particles of sand separate, and are precipitated, after which the oil is pumped into measuring reservoirs (accurately gauged and provided with gauge-glasses and drain-cocks to expel any settlements of water) erected above ground, where it awaits disposal. On Government leasehold lands all the valves connected with reservoirs are sealed by an official, whose daily duty it is to visit the property, measure the oil after running off the water, and give the necessary permit for its removal; but all valves and fittings must be exposed and planned according to instructions given by the inspector, and each day only such valves will be left unsealed as lead from the reservoirs of measured oil, which the official has noted in a book kept for this particular purpose, after agreement with the lessee's representative.

Most of the large Balakhany-Saboontchy producing and refining firms possess their own pipe-line or lines from a central pumping station on the oil fields to their refineries at Blacktown; but for the benefit of smaller companies not so fortunately placed, there are pump-stations which will accept the oil and pump it to the refineries at a fixed charge. The price is usually 2½ or 3 per cent. for pumping and shrinkage, which latter term means an allowance for a small proportion of suspended water in the oil and leakage in the pipe-lines. When oil is received in this manner, an inspector is sent from the station to measure the oil in the tanks, and assure himself of the correct quality and absence of water and dirt, and to close and seal all valves through which the oil could escape in any way, after which the pump is set to work, and nothing must be touched until the inspector returns and removes the seals. There are several public pump-stations in the Balakhany-Saboontchy field, viz., the Baku, the Balakhany, and the Adamoff, which charge from 2½ to 3 per cent. for receiving, storing, and delivering the crude oil to Blacktown; but sales are often made direct to refining companies who possess their own pipe-lines, in which case 2½ to 3 per cent. is also deducted from the quantity pumped. The pump-station companies (*neftiprovod*) own a system of pipes encircling the district along the principal roads, and the sellers have usually to make their own connections to this line. Fountain oil is generally pumped direct to the pump-stations, and there measured, the amount being agreed upon by representatives of both parties; but, except where stated to the contrary, the measurements of oil take place on the producing property.

The oil from the Bibi-Eibat field is conveyed to the refineries at Blacktown in barges drawn by steam-tugs, which ply to and fro across the Baku Bay. The large producing firms have their own wharves, barges, and tugs; but there are also contractors who undertake the transport of petroleum from Bibi-Eibat to Blacktown at a cost of about 1 rouble per 1000 poods.

The wharves at Bibi-Eibat are long timber structures which extend far enough into the sea to ensure the barges loading in safety, and along these are conducted 6-inch and 8-inch pipes which convey the oil from the shore to the barges. The oil is pumped into measuring tanks on the shore, raised, in some cases, to a sufficient altitude to induce a flow by gravitation; but where such an arrangement is impossible, the oil is pumped to the boats. The barges in use conveying the oil from Bibi-Eibat to Blacktown have a capacity of 40,000 to 70,000 poods, and can be filled at the rate of 25,000 to 30,000 poods per hour, and some firms can comfortably dispose of from 600,000 to 700,000 poods a day. The whole of the Binagadi oil is despatched to the neighbouring villages, either in barrels supported by carts, or in skins on the backs of camels, and it finds a ready sale amongst the peasants of the district.

Table IV. gives a list of all the pipe-lines, with their lengths and capacities, between the Baku refineries of the Balakhany-Saboontchy oil field.

Excise Duty.—All refined kerosene in Russia taken outside the boundary of the district appropriated to the use of refineries, except that destined for export to foreign countries, is liable to an excise duty of 60 copecks a pood, which produces the somewhat ludicrous situation that burning-oil in Baku—lying between the two richest oil-producing grounds in the world—costs about as much as the same article is sold for in London. At times the price of crude oil has been about equal to that of kerosene, as, for instance, in April, 1901, when crude was about 7·5 copecks per pood, and kerosene in ships 7 copecks per pood, so that the effect of the excise duty was to cause a needy article to exceed its real commercial value and the worth of its matrix ten times over. The low price of kerosene, which lasted till about the middle of 1902, was brought about solely by the enhanced value of astatki which is not liable to any excise duty, but for which a demand had arisen far in excess of the refined article, through the extension of liquid fuel into the Russian manufacturing centres. To one used to seeing free trade in all necessities, unrestricted by even small duties, the imposition of such a tax appears monstrous; for it is evident that the chief demand for kerosene comes from the poor, agricultural, and labouring classes, who depend upon this oil for lighting purposes wherever its distribution has reached, and it is affirmed that millions of poor Russian peasants are debarred from the use of an illuminant in

TABLE IV.

GIVING SIZE, LENGTH, AND CAPACITIES OF ALL PIPE-LINES BETWEEN BAKU REFINERIES AND THE BALAKHANY-SABOONTCHY OIL FIELD.

Name of owner.	Diameter in inches.	Length.		Maximum capacity in poods per day.
		Versts.	Sagenes.	
Assadulaieff	4	12	200	75,000
Adamoff Bros.	4	12	44	40,000
" "	4	11	470	55,000
Antonoff, O E.	4	9	330	60,000
" Aramazd ".	6	11	354	150,000
Baku Oil	6	10	—	160,000
Balakhany Oil Co. . . .	5	7	320	100,000
" "	5	7	320	100,000
Baku Oil Co.	5	9	416	120,000
" "	6	9	434	100,000
Baku-Russian Oil Co. . . .	3	10	356	30,000
" " "	4	12	—	60,000
" " "	4	14	67	60,000
" " "	6	10	356	150,000
Caspian Co.	5	9	269	150,000
" "	4	9	269	60,000
Caspian Water-line . . .	10	9	269	500,000
" "	12	9	269	800,000
Caspian and Black Sea Co. . .	6	8	282	200,000
" " " . . .	8	8	282	200,000
" Kavkas " Co.	3	10	—	30,000
Mantasheff and Co. . . .	6	8	165	115,000
" "	8	8	440	220,000
Mirzoeff Bros. and Co. . . .	3	12	—	30,000
" " "	4	12	—	60,000
" " "	5	12	—	70,000
" " "	7	8	254	100,000
Melikoff, A. C., and Co. . . .	4	12	260	30,000
Musa Nagieff	5	11	300	125,000
Nobel Bros.	4	8	233	30,000
" "	5	8	233	100,000
" "	6	8	233	100,000
" "	6	8	233	70,000
" "	8	8	233	200,000
Russian Oil Co.	3	11	300	40,000
Schibaieff Petroleum Co. . .	3	8	—	30,000
" "	4	8	165	60,000
" "	6	8	165	150,000
Tumaieff and Co.	3	14	—	30,000
Total	—	394	21	4,760,000

their cottages by the terms of this tax, and millions of villagers have still to use the old-fashioned candle, or improvise a dim light for their homes by extracting fat from flesh and burning it in a small tin.

Some authorities assert emphatically that the imposition of the tax on kerosene has, notwithstanding its immense value, resulted in a loss of revenue to the State; for, in the first place, the fall in value of kerosene through the limited demand has led to the enhanced value of astatki—an article largely purchased by the Government—and, secondly, the high price of residue compared with kerosene has led refiners to extract a much less quantity of the excise-producing material than would be the case in normal times. It has been estimated that refiners have extracted about 12½ per cent. less kerosene from the crude oil than they would have done had the price of kerosene exceeded that of astatki, and, as a consequence, the Government has lost the excise duty on about 50,000,000 poods of kerosene annually, which is equivalent to nearly £3,000,000 a year revenue, the loss being aggravated by the fact that refiners not only abstracted less kerosene, but they mixed crude oil with their astatki to bring it to the very limits of the legal standard. Table V. shows the actual amount of kerosene extracted annually, since 1889 which proves the verity of the last statement. As the Russian State railways consume about 50,000,000 poods of astatki annually, it is apparent that the high price at which the Government must purchase its fuel acts as a serious counter-influence against the excise on kerosene, besides influencing industries which indirectly affect the country's revenue. The production of oil from Russia is practically unlimited, and the Government could, by leasing out more lands, assure as much oil as it deemed expedient within twelve months, so that were the excise duty

TABLE V.

SHOWING PRODUCTION OF CRUDE OIL AND QUANTITY OF KEROSENE EXTRACTED ANNUALLY SINCE 1889 IN BAKU (IN POODS).

Year.	Production of Crude oil.	Kerosene extracted.	Percentage kerosene to crude oil.
1889	192,000,000	61,145,000	31·8
1890	226,000,000	63,673,000	32·6
1891	274,000,000	78,831,000	28·8
1892	285,000,000	82,239,000	28·8
1893	324,000,000	89,452,000	27·6
1894	279,000,000	67,849,000	22·8
1895	377,000,000	87,563,000	23·2
1896	386,000,000	91,051,000	23·6
1897	421,000,000	91,373,000	21·7
1898	486,000,000	96,125,000	19·8
1899	525,000,000	113,991,000	21·7
1900	601,000,000	134,108,000	22·3
1901	671,000,000	128,651,000	19·5
1902	636,000,000	135,072,000	21·2
1903			
1904			
1905			

on kerosene removed or reduced to a fraction of its present amount, and its sale therefore increased, it is reasonable to suppose that the demand would be accompanied by a higher market price and a diminished cost of astatki, from which the Government would benefit in three ways; first, by the extra royalties collected on crude oil raised; secondly, by the extraction of the maximum quantity of kerosene from the crude; and thirdly, by the reduced cost of fuel on the railways and in the manufactures.

It has been stated by a Russian journal that a family consuming 2 lbs. of oil per day, or 18 poods per year, pays to the State no less than 12 roubles 60 copecks (26*s.*) for an article which costs at the refinery only 1 rouble 26 copecks (2*s.* 6*d.*) to 1½ rouble (3*s.*) at times, and that the consumption of kerosene per head of population in Russia does not exceed half a gallon per year (in England the consumption exceeds 1·5 gallon per head per annum), so that the heavy, indirect taxation levied on the working classes and the immense influence the duty has on the sale of kerosene is apparent from these figures.

All kerosene exported from the precincts of the refineries is under the control of the authorities, and is subject to a duty of 60 copecks a pood. Instead of paying cash, which would seriously impede the growth of the industry, an obligation note, termed an excise bond, is obtained from the officials to the value of the duty on the exported oil, that allows the consigner nine months in which to pay. On satisfying the authorities that the kerosene has been exported from the country the amount is credited to the consigner.

Distribution of Petroleum Products in Russia.—Until a few years ago, practically the whole of the Russian oil extracted was consumed in Russia, the chief demand for astatki coming from the manufacturing districts on the banks of the Volga, and the market for kerosene extending wherever the railways, rivers, and canals permitted its transportation and delivery to large towns and rural populations. The Caspian Sea was obviously the cheapest and at one time (till 1898) the only route to the Central Russian markets, whilst the Volga, with its fine system of canals stretching out in all directions, naturally became the chief highway for the distribution of the Baku products. It was only in 1898 that the main railway system of Russia was connected with Baku by means of a line constructed from Petrovsk along the Caspian shore, but at any rate the carriage of oil in bulk can be much more economically and expeditiously conducted in tankers than overland on railways, so that the establishment of railway communication in this direction has not materially affected the Baku oil industry, although it has greatly facilitated the passenger and goods traffic. The construction of the railway from Vladikavkas to Petrovsk had previously performed the important duty of putting the Grosny field in communication with the rich industrial centres of South Russia, and with a Black Sea and a Caspian sea-port, so that it was the means of giving this region a good outlet for its products, and to a district where Baku oil could not compete.

Baku is exceptionally well situated for the disposal of the Apsheron products, for the refineries are built in a suburb of Baku on the shores of the Caspian, in a splendidly protected bay with safe anchorage for any number of vessels, where the filling of tank-steamers can be rapidly executed; it is now connected by a direct railway line with the Black Sea; and it has, besides the

Volga trade, an outlet into the Trans-Caspian provinces by means of a railway into the interior of Asia from Krasnovodsk. The internal trade is conducted almost exclusively from Astrakhan, where the steamers from the southern ports have to discharge their cargoes into barges at a distance of 100 miles from the town, as the ever-changing approaches to the Volga are too treacherous and too shallow for vessels of over 9 feet draught. The Volga itself is the fourteenth largest river in the world, being 2325 miles long, but inclusive of the intricate system of lakes, canals, etc., having connection with it, the length is 30,600 miles, nearly 10,000 miles of which are navigable by ships.* For more than 40 miles from the shore at Astrakhan the greatest depth of the water does not exceed 9 feet, and when a stiff north-east wind blows, the depth is reduced to as low as 2–4 feet, and the trans-shipment of cargo has to be postponed until a south-easterly wind sets in, or the weather calms. Notwithstanding the many difficulties of discharging cargoes, etc., in such an exposed and difficult position, the number and size of the oil-carrying vessels have annually increased, for statistics published by the Committee of Naphtha Producers show that the number of steamers has risen from 34 vessels in 1899 to 126 in 1902, and although the sailing-vessels have decreased in number from 294 to 157 in the same period, the total capacity of the fleet has risen from 7,300,000 poods in 1899 to 12,000,000 in 1902, or 64 per cent.

Thirty-seven per cent. of the oil steamers trading between Baku and Astrakhan have a capacity of 50,000 poods or less of astatki, and 63 per cent. have a capacity exceeding this quantity, a few of which are capable of conveying 100,000 poods.

All the North Caspian sea-ports are frozen up during the four winter months—November to February inclusive—so that navigation is confined to the remaining seven or eight months, when all the tankers are actively engaged on the service. It is, of course, unfortunate that the means of admitting kerosene and astatki into the oil-consuming districts should be closed when the demand for kerosene, at least, is greatest, and the closing of the chief outlet causes stocks to collect at the Baku refineries, invariably having the effect of lowering the price of crude oil for immediate deliveries; but as soon as favourable reports are received concerning the breaking up of the ice in the northern rivers, navigation opens, the market improves, and the stocks of oil collected during the suspension of shipping begin to diminish. The distance from Baku to Astrakhan is 600 miles, but the steamers drop anchor in the roadstead about 100 miles from Astrakhan, so that the distance actually traversed is only about 500 miles. Steamers perform one return trip in about three days, the time being occupied as follows:—

Loading at Baku	3 hours
From Baku to Astrakhan roadstead	34 „
Unloading in roadstead	4 „
Return journey empty	32 „

Under favourable conditions seven to nine journeys a month can be made. Sailing-ships are able to make about eight trips backwards and forwards during the navigation period, but these usually return with other cargoes. The freight charged from Baku to the roadstead of Astrakhan is 1·75 copeck per pood for astatki, and 2·25 to 2·50 copecks per pood for kerosene, as well as an allowance for fuel and leakage, collectively estimated at 6 per cent. The extra charge for the conveyance of kerosene is due to the reduced specific gravity and the greater leakage; the capacity of the steamer being lessened by 10 per cent. to 12 per cent. when loaded with kerosene. Insurance can be effected at a moderate rate between Baku and Astrakhan. In the busy navigation period the roadstead at the mouth of the Volga presents an animated appearance, for quite a town springs up in the sea, nearly 100 miles from land, to deal with the transference of the cargoes into barges for transport to Astrakhan. In this marine station the custom-house authorities have a vessel where all the official business connected with the customs is transacted; there is a telegraph station, where all information may be telegraphed referring to the motion of vessels; there is a general store where goods may be purchased; a hospital-ship is detained for the treatment of sick and injured sailors, etc.; and each of the important firms who carry on a large shipping trade owns a vessel upon which a big staff of clerks and attendants reside permanently during the season, and conduct the business connected with the acceptance and transfer of cargo. These floating dwellings return to Astrakhan on the approach of winter, where they are stored until the following navigation period.

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* The "Encyclopædia Britannica" states that no less than 14,500 miles are navigable by ships.

In the Astrakhan roadstead the incoming steamers are met by barges (both wood and iron) into which the oil is pumped by powerful steam-pumps, but, for the convenience of sailing-vessels not so provided, there are several barges supplied with pumps for transferring the cargo. The barges, which are specially built to withstand the rough sea treatment they are liable to meet with, perform the journey to Astrakhan fully laden and against the current in 35 to 40 hours, the return trip, empty, occupying only about 19 hours. At Astrakhan the oil is either pumped into storage tanks on the wharves, owned by the various distributing companies, or it is transferred to river-barges, in which it continues its passage up the Volga to its destination, or to a railway connection leading to its destination.

All the mouths of the Volga are difficult to navigate owing to their shallowness and the frequency of currents and sandbanks, but the Bakhtimera Channel is generally taken advantage of for the transit of barges, as it presents the fewest objectionable features. There are between 250 and 275 barges, having a total capacity of about 14,000,000 poods, occupied constantly in transporting the oil from the sea-steamers to Astrakhan, and during the period of navigation between 300,000,000 and 400,000,000 poods of petroleum products are conveyed by this fleet of barges. The journey up the Volga is not without its difficulties, for the large towns on its banks are ill provided with wharves where the vessels may discharge their cargo with ease; sandbanks and swift currents are frequently encountered, which delay and even endanger the safety of the boats; and there is the long severe winter, when the whole of the Volga flotilla has to seek refuge as best it can, followed by the breaking up of the ice in the spring, that causes damage to the unprotected shipping to the extent of at least £10,000 annually. The following is a list of the most important towns on the banks of the Volga, and by the side of each is given the distance from

Astrakhan in versts and English miles, and the populations of the more important places:—

	Versts.	Miles.	Population.
Tzaritzin . . .	464	309	—
Kameshin . . .	627	418	—
Saratoff . . .	844	563	123,000
Sezran . . .	1136	757	—
Batrakoff . . .	1145	763	—
Samara . . .	1249	833	75,500
Kazan	1669	1113	140,000
Nizhni-novgorod . .	2042	1361	98,500
Kineshma . . .	2237	1491	—
Kostroma . . .	2338	1559	28,200
Yaroslava . . .	2462	1641	—
Rebinsk . . .	2494	1663	—

Tzaritzin is the first important town used for the storage of petroleum products to await subsequent despatch on the railways, and at this centre there are 119 reservoirs, having a total capacity of about 11,600,000 poods of oil, belonging to the various companies engaged in the distributing business. The wharves are connected to the storage installations by pipe-lines of 2 inches to 8 inches diameter, Nobel Bros. owning no less than eight pipe-lines of varying sizes, and possessing storage for nearly 4,000,000 poods of oil products.

When the railway from Baku to Batoum was opened, the oil industry of the Caucasus received a new lease of life, for this gave a means of disposing of all the surplus oils by securing an outlet at a sea-port in direct communication with the oceans. At first the railway could easily deal with the quantities delivered for transportation, but as the export trade extended, and the demand for Russian oils increased, the congested traffic soon made it apparent that the single-line railway could not possibly convey the quantities of oil to Batoum that might be sold, and that improved means of transport must be arranged. English and Russian capitalists were anxious to construct a pipe-line between the two places for the conveyance of kerosene, but the Government would agree to no such scheme being conducted by private enterprise, as it was considered that the revenue from the railway would be diminished and cause competition; and it was not until 1897 that the Government itself, after much agitation, undertook the construction of a pipe-line over part of the distance. The gradient of the railway from Baku to Michaelova is a very steady one, but from this place to the summit of the range the ascent is very steep, necessitating the division of the goods trains and the employment of extra engines to drag even light trains over the summit. The Government, therefore, constructed the first portion of the Trans-Caucasian pipe-line along the railway from Michaelova to Batoum, a distance of 140 miles, to remove this difficulty, an 8-inch pipe-line being laid, intercepted by storage accommodation and pump-stations at intervals. In 1900 the work of extending the pipe-line to Ag-Taglia was commenced, and the Government has since authorized the continuation of the line to Baku, in preference to expensive alterations on the railway, which would in any case only afford immediate relief and be but a temporary solution of the problem.

The pipe-line, on completion, will be capable of delivering about 65,000,000 poods of kerosene per annum, which is about the same as can be conveyed on the railway in its present state, but if certain alterations are made on the line, it is estimated that it will be able to transport about 100,000,000 poods of oil a year. If it is reckoned that 33⅓ per cent. of kerosene is on an

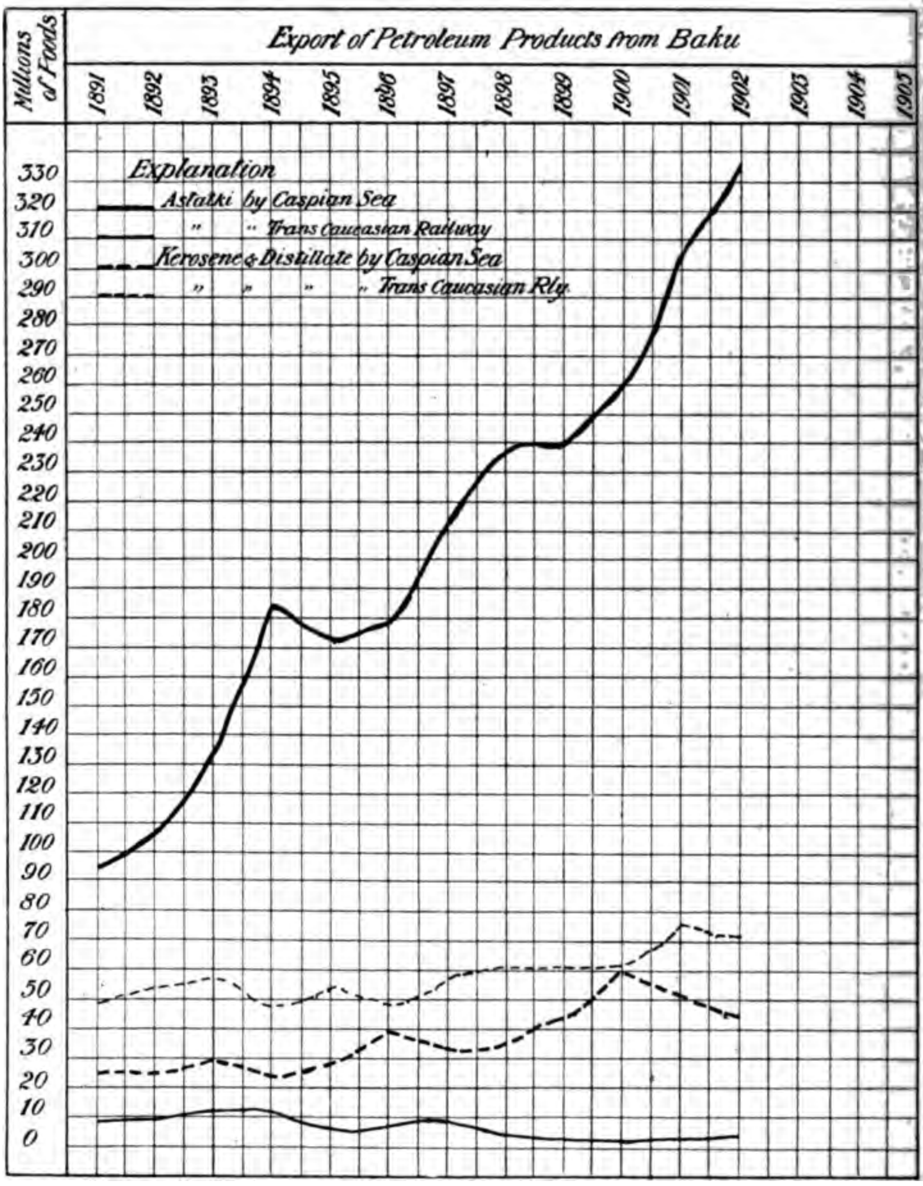
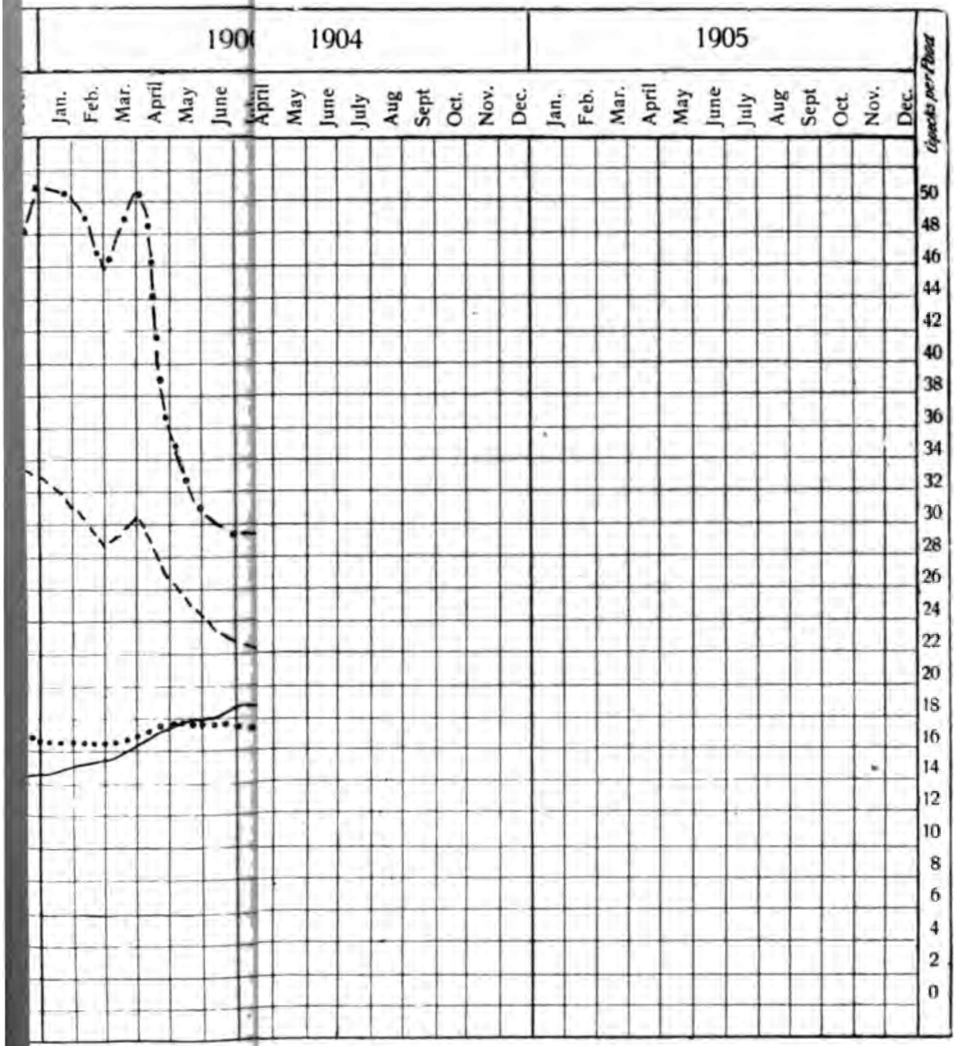


Fig. 5.—Graphic Representation of Baku Petroleum Exports since 1891.



ing Prices of Crude

[To face p. 30.

average extracted from Baku crude oil, the combined connection with Batoum will give facilities for exporting the distillate from about 495,000,000 poods of petroleum, or rather more than three-fourths of the present Baku production; but it must not be overlooked that a big demand for astatki is likely to arise for supplying Eastern-bound steamers with oil fuel at Suez, etc., during the next few years, in which case the railway will be kept fully occupied with the transport of this article.

In order to simplify the delivery of kerosene from Baku, a pipe-line is in course of construction between the refineries and Wolf's Gate, at which point storage will be erected, and the Trans-Caucasian pipe-line will have its primary station. The object of this arrangement is to avoid the big sweep of about 25 versts that the railway makes in approaching Baku, and to escape the steep gradient which the railway line traverses in surmounting the ridge dividing Baku from the sea-level station of Wolf's Gate.

It was estimated by engineers, in 1901, that the cost of transporting 1 pood of kerosene from Baku to Batoum in tank-waggons was 3·9 copecks, but the cost by the pipe-line, calculated on a basis of 50,000,000 poods a year, will not exceed 1·2 copeck, so that a substantial decrease in the freight ought to follow the completion of the scheme if the figures prove correct in practice.

Special attention has been paid to the means of finding a ready market for kerosene, as this is at present the drug in the market, its low value diminishing the profits of refining to a minimum, and it is generally admitted that an improvement in kerosene will be followed by a fall in prices of residuum, and consequently an increased demand which will keep pace with the increased production of kerosene. An equalization of prices is necessary for the producers, refiners, and users of liquid fuel; for it is an unnatural situation for a refined article to have a less value than the crude material or the residue, and the industry can only flourish if each product has a proportional value and a free sale.

Fig. 5 shows graphically the export of petroleum products from Baku since 1891, and Fig. 6 graphically illustrates the fluctuations of Baku prices for oil products since the year 1896.

Grosny suffers from the same transport difficulties as Baku on an exaggerated scale, for the oil fields are entirely dependent upon the Vladikavkas Railway for the removal of their oil, having no immediate sea-port where it could be put into tankers. Exported oils are sent to Novorossisk on the Black Sea, a port which is rapidly increasing in importance, and oils for home consumption are sent to the Caspian sea-port of Petrovsk, to both of which places schemes for pipe-lines have been proposed for relieving the stocks.

On account of the limited number of tank-cars owned by the railway authorities on the Trans-Caucasian and Vladikavkas lines, there is a keen competition for securing them, which has made it necessary to devise schemes from time to time for their fair distribution to the refineries. During the last few years the annual demand for tank-waggons has doubled that of the number available, so that it has been a difficult matter for the authorities to give general satisfaction. A select committee of the Naphtha Producers' Association is now given the duty of making a division of the tank-cars in consultation with the railway officials, in proportion to the actual quantity of petroleum treated, so that the distribution is not dependent upon the size or capacity of the refinery, but upon the amount refined. The enforcement of this regulation has laid a heavy burden upon the shoulders of small refiners, who are compelled to continue their refining to the full capacity, even at a loss, in order to secure the transport of their products on the railway—an unjust treatment, it may be said, but one which it is difficult to avoid under the existing circumstances.

Originally tank-cars were held privately by refiners, but many years ago the Government passed a law deciding that these should not be in the hands of private individuals, and an enforced sale was ordered in accordance with regulations issued for their purchase. It was the abandonment of the private tank-car and the lack of energy on the part of the Government that led to the great variation in price of kerosene between that in tank-waggons and that on board ship (see Fig. 6).

Distribution of Russian Oil in England.—Russian kerosene was first introduced into the English market in 1883, at which time the American illuminating oil had obtained a firm hold of the British trade, and was being utilized at the rate of about 1½ gallons per head of population per annum, at a price of about 9*d.* per gallon. Messrs. Rothschild were the first financiers to negotiate with English capitalists for the formation of a distributing business in Great Britain, with the result that the Kerosene Co. was formed, but soon afterwards the Tank Storage and Carriage Co. was floated and worked in conjunction with the former concern, and until Messrs. Rothschild organized their private distributing company, called the Anglo-Caucasian Oil Co., the two concerns marketed Rothschilds' oils on a commission basis.

Nobels then entered the English trade, and appointed Messrs. Bessler, Waechter and Co. to be their sole agents in the United Kingdom for the distribution of Russian oil, which was shipped from Batoum. Subsequently a combination was arranged between the two competitive companies of Nobels and Rothschilds, the coalition trading under the name of the Consolidated Petroleum Co., and this large enterprise, by arriving at a definite arrangement with the Standard Oil Co.'s agencies in England, has been able to sell kerosene at a huge profit without any competition. It has been stated that the Consolidated Petroleum Co., being practically the sole exporters of Russian kerosene, only shipped sufficient oil from Batoum to keep the price low, and having no competition in England, they were able to reap a rich harvest from the depressed Russian market; but it must not be overlooked that both these firms have wider interests than those centred in England, and if huge profits were made, it was on account of all absence of competition, and proves conclusively how the Russian oil could, under favourable conditions, swamp the American article.

A recent combination has been formed of Baku refiners, consisting of the Russian Petroleum and Liquid Fuel Co. (in which is incorporated the Kerosene and Lubricating Oil Co.),* Mantasheff and Co., and the Caspian Society, which will trade under the name of the Caucasian Petroleum Co., and actively enter the remunerative distributing business in the United Kingdom. It is anticipated by those who can speak authoritatively that the oil-industry as a whole, as well as the English consumers, will benefit considerably by the coalition of such powerful firms, for the enormous profits derived from the sale of Russian oil in the United Kingdom during the last two years can be seen by comparing the comparative prices in Baku and London. In March, 1900, Baku kerosene on railway was 50 copecks per pood, and in London 7*d.* per gallon; in March, 1902, the prices were 6 copecks per pood in Baku, and 6¼*d.* per gallon in England, and the Baku price has never exceeded 16 copecks per pood since March, 1901; still English prices hold.

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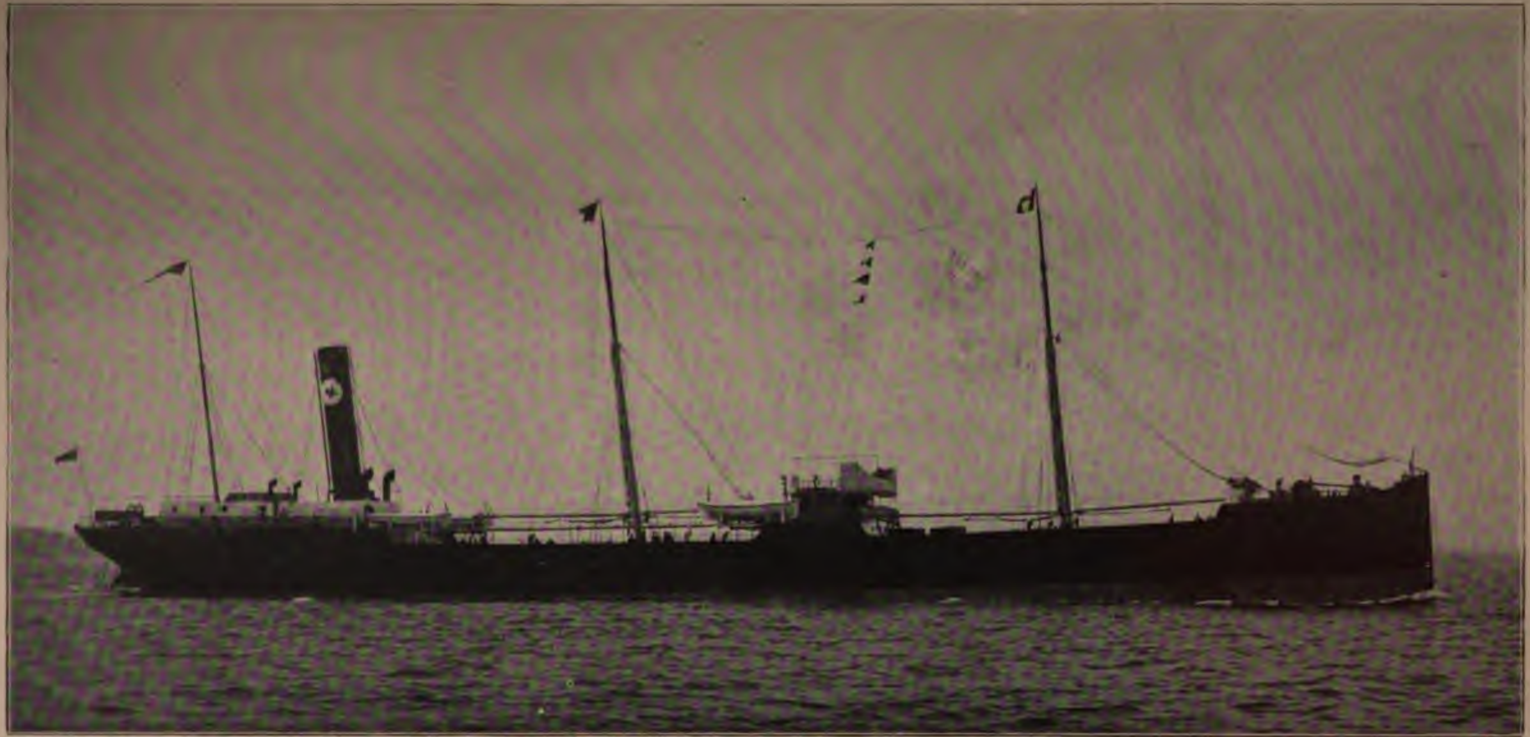
* This company has since severed its connection with the new distributing business, but the firms of Matasheff and the Caspian Co. are actually at work in the United Kingdom, under the title of the Caucasian Oil Co.

The Severe Oil Crisis of 1900 and 1901.—After the price of crude oil had remained steady for nearly three years at about 8 copecks per pood, it commenced to rise in June, 1898, and continued to do so almost without interruption until it reached the abnormal figure of 18 copecks a pood in April, 1900, when, after standing almost stationary for a few months, it began to decline, and within eight months (April, 1901) had fallen to only 7½ copecks per pood. In June, 1898, the price of astatki started to rise from 8 or 9 copecks, at which it had been also a long time, and reached 19 copecks in June, 1900 (see Fig. 6), a figure which seriously affected manufacturers who relied upon residuum for their fuel; indeed, thousands of factories were erected on the Volga solely on account of the cheapness of fuel. The general good trade throughout Russia during 1898 and 1899 enabled the proprietors of industrial establishments to pay the high price for the fuel, but on the appearance of the acute depression of business following the boom, they found themselves considerably handicapped by the expensive nature of fuel, and were in many cases forced to return to coal. Oil fuel will be employed by all users of power even if its price slightly exceeds that of coal (when due allowance is made for the difference of thermal value), on account of the peculiar conveniences attending its manipulation; but as it has been shown that when the price of astatki is above 10–12 copecks in Baku, coal can compete with and will replace the residuum in many of the industrial centres of Russia, it is essential for the success of the oil business that the price of astatki should not be allowed to rise above this figure.

When the oil boom was approaching its zenith, there was an enormous influx of new capital into the business, for immense fortunes were being realized by holders of productive properties, and great activity in boring work was everywhere in evidence; oil lands were changing hands at ruinous prices, and Government plots leased out by auction in the Bibi-Eibat and Saboontchy districts were readily accepted at a royalty of from 6 to 12 copecks a pood. Ultimately, the enormously increased production exceeded the demand, for stocks commenced to accumulate, and although unbounded faith in the security of the industry, and plausible excuses for the situation held prices up for a time, a panic ensued when merchants saw that there was no market for their goods. A severe crisis followed the fall of prices in 1901, and lessees of royalty plots at a high rate were compelled to cease operations entirely or work at a great loss, whilst other syndicates, more favourably situated, were forced to reduce expenses and to diminish the extent of their exploitation. Retrenchment was the order of the day, causing thousands of workmen to be thrown out of employment, to whom the Government gave free passages to other centres of industry, to prevent disturbances, and a severe strain was put upon the financial resources of Baku and other merchants.

Many explanations to account for the depressed state of the oil trade have been forthcoming from influential people connected with the oil industry, and numberless schemes for improving the conditions have been suggested by specially appointed committees, Government commissioners, and private individuals, but the most satisfactory explanation is probably that which puts it down wholly and solely to over-production, although such a state may be indirectly traced to Government restrictions placed on the business. The chief reasons advanced by oil merchants for the crisis are that the excise duty limits the home consumption of kerosene, and that there are insufficient and inadequate means of exporting oil from the country, the absence of a pipe-line and the small number of tank-waggons available or capable of the transit across the Trans-Caucasian Railway, being the cause. Britishers, as free-traders, have naturally an aversion to the taxation of a needy article which does not fall under the appellation of a luxury, but the Russian Government has to collect a revenue for administering a huge empire from some source, and to place a direct tax on the immense uneducated population of Russia, who neither see nor understand that they are being taxed by the indirect form, would meet with a serious opposition, if not a popular uprising, so that it is not proper to criticize too severely a tax which may, after all, not materially affect the situation. The removal or reduction of the excise duty on kerosene would, without doubt, create an enormously increased demand, which would just as readily be met on account of the almost limitless oil-bearing lands of the Caucasus; therefore its effect on prices would be of a temporary nature only, and produce no permanent improvement, although it is possible the Government might gain by the change. The export facilities are, however, of immense importance to Russia if the empire is to alter from an importing to an exporting country, and there should be unlimited means of despatching the whole of the surplus stocks to other lands.

Great stress has rightly been placed upon improved connection with Batoum and Novorossisk, the nearest tidal ports to Baku and Grosny respectively, and the Government has works in hand that will, when completed, remove the congested traffic difficulty on the Batoum route; but the absence of such facilities has not been the direct cause of depression, for during the crisis the storages of Batoum were full to overflowing, and not reduced to a low state, as would happen were the transport arrangements unable to deal with the oils. Indirectly, the poor communication with Batoum, and the imposition of Government restrictions in the way of preventing private enterprise may have affected the export trade by delaying English and other shipping companies from trading with Russian oil, for such concerns would scarcely attempt to build up a large business unless they saw prospects of a permanent supply without unreasonable fluctuations of price. The Russian Government has now, however, taken measures for securing an easy transport of oils destined for export, which



From "Petroleum."

Fig. 7.—A Modern Ocean-going Tanker of British Build.

THE NEW YORK
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ASTOR, LENOX AND
TILDEN FOUNDATIONS.

are freed from excise duty, and if only a moderate charge is made for the conveyance of kerosene to the Black Sea ports, and no annoying regulations and unfair dues are imposed, a huge export trade, rivalling, if not exceeding, the American business, will be built up in a very few years. As the export trade to England has been monopolized for years by the two firms of Rothschild and Nobel acting in concert, and the Eastern trade has also been in the hands of one or two powerful houses, there has been practically no competition, and until other companies enter the field, little improvement will be made.

Various concessions were granted to the Baku refiners by the Government, to assist them in the disposal of their products, amongst them being a rebate of freight on all oil destined for export conveyed by the Trans-Caucasian Railway. The reduction allowed was equivalent to a difference of 11 copecks per pood; but owing to the excessive demand for tank-cars with delivery at Batoum at a specified date, a keen speculation arose, which caused a premium to be placed on tank-waggons nearly equal to the sum conceded, thus causing the concession to fail in attaining its object.

The over-production which has led to the oil crisis has been attributed to the following causes, all of which, acting in conjunction and simultaneously, may have been instrumental in leading to the situation: The payment of royalties, on Government-leased plots, on a minimum production, the clauses in the same contracts stipulating a reducing royalty with an increase of production; and the system of allotment of tank-cars. In accordance with the terms of the contract with the Government, the lessees are compelled to extract a defined quantity of oil from their properties, whatever the state of the market; and if they wish to avail themselves of the additional inducements offered in the agreement, they must exploit their holdings to the greatest extent possible; in fact, on a fall of prices, a profit can only be assured by the extraction of sufficient petroleum to reduce the royalty per pood. Conditions of this nature inserted in the agreements serve to aggravate the situation at times of over-production, for leaseholders are forced to raise the stipulated amount of oil, even at a loss, to escape what is practically the imposition of a fine if the leaseholders assist the recovery of the market by reducing exploitation. The division of tank-waggons, on the before-mentioned lines, influenced the output of the refineries by compelling refiners to work to their fullest capacities in order to secure the maximum number of railway tank-cars for the conveyance of a proportion of their products to the sea-coast. The prospects of an improvement of the Russian petroleum industry in 1903 are brighter, for the production is falling, and there is a slight rise of prices of crude and astatki, and a decided upward turn in kerosene; but the urgent requirements are freer facilities for distribution in Russia, and more active exertions to secure a larger export trade and sale of products in foreign countries.

The crisis in the oil industry was made more acute by the accompaniment of a money crisis, which greatly exaggerated the general depression, and caused many business firms to suspend operations almost entirely. The shortness of cash was said to be due to the heavy payments that had to be made to the Government in the form of guarantee money, royalties on produced oil, duty on imported goods, and excise duty, which drained Baku of all ready money for a time, and ran the cost of discounting up to a high figure.

The Grosny producers attempted to protect themselves during the crisis by forming a combination, the members of which undertook to sell no oil under a price of 10 copecks a pood. The desired effect of keeping up prices was attained, but not without the participators suffering losses, for all the Grosny producers could not be induced to take part in the combination, and this led to underselling, which considerably embarrassed the combine, and caused large stocks of oil to accumulate in their hands.

A Volga Oil-carrying Barge.

CHAPTER II.

COMPOSITION AND SPECIAL FEATURES OF THE OIL DEPOSITS, AND DATA RELATING TO THE DISTRIBUTION OF OIL THROUGHOUT THE STRATA.

Interpretation of Boring Journals.—Imperfections of percussion system in giving geological information—Corrections to be applied to descriptions—Preparation of well-section.

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Geological Conditions Necessary for the Reception and Preservation of Petroleum.—Need of porous stratum with impervious covering for accumulation of petroleum—Value of anticline for the aggregation of large volumes of petroleum—Probable limited influence of anticlinal structure on the distribution of oil in the Russian oil fields—Important observations bearing upon the aggregation of petroleum in the oil fields of the Apsheron Peninsula.

CHAPTER II.

COMPOSITION AND SPECIAL FEATURES OF THE OIL DEPOSITS, AND DATA RELATING TO THE DISTRIBUTION OF OIL THROUGHOUT THE STRATA.

Interpretation of Boring Journals.—The percussion system of boring wells does not permit a very accurate knowledge of the strata being obtained, for the material from one source is pulverized and mixed with that of another, so that at best only an approximate idea of the nature of the ground is procurable. This practice—for nearly all wells are drilled by the percussion principle—has served to diminish the geological value of well-sections, and to mystify specialists and geologists who have only the boring journals and official publications upon which to base their conclusions.

It is quite certain that, in many cases, the usual records kept to fulfil the demands of the Russian Mining Department fail entirely in giving the information desired, and it is quite obvious that, unless discrimination and judgment are used in their compilation, only confusion arises. Suppose, for example, a bed of sand has just been passed, and a clay is reached; now, for some distance into the clay formation there will be more or less sand from the stratum above, which will be mixed with the detritus raised in the cleaning augers, and although a correct description of the *débris* is "clay with sand," there may not be a particle of the sand with the clay *in situ*. The reverse of the above might be the case, but usually the boring-masters do not incriminate themselves by any speculations under this head, and consider their instructions fulfilled by writing in the daily boring journals what material was actually raised.

In studying a boring section, too much reliance must not, therefore, be placed upon the absolute verity of the statements describing the nature of the ground; but realizing these facts, and possessing an intimate acquaintance with the reigning conditions, one may, by using discretion, draw a geological diagram of value. In the preparation of boring returns a regular systematic style is sometimes, and should be always adopted by which a clearer idea of the character of the strata may be obtained. Thus, a remark, "clay with sand," would indicate a preponderance of the former, whilst an insertion, "sand with clay," would convey the impression that sand predominated. If any distinctive colour is prevalent it is noted and prefixed to the material which imparts it; but when there is no decided tint that would attract attention no mention is made of this quality. "Sand" signifies anything in the geological reports, but if so nominated without other observation, it is understood to possess no particular interest that requires other designation, is neither oil, gas, nor water-bearing sand, as far as can be ascertained by a casual inspection, and may possibly be finely pulverized sandstone. Recognized oil sands are recorded as such, dry sands impregnated with a decided petroleum odour are classified as gas sands, and clays saturated with oil are recorded as oil clays.

In the preparation of a well-section the draughtsman must use discrimination, but he may fairly safely infer that if "clay with sand" appears for a number of feet after sand has been passed, merging ultimately into clay alone, the distance so termed is clay mixed only with overlying sand. Sometimes beds of clay and sand follow one another in rapid succession, when the nomination of "clay with sand," or *vice versâ*, would more accurately describe the actual state, but it is impossible to know this unless large cavings are brought up, as sometimes happens, on the bits. The number of feet bored in a definite period also gives a fair idea of the nature of the strata to one who has had local experience in boring, for from this item a skilled person will derive much valuable information.

Description of the Strata forming the Oil-bearing Series.—The oil-bearing strata of the Apsheron Peninsula are covered in many places by a local series of beds composed mostly of yellow sands and highly fossiliferous limestones, which, apparently, lie conformably over the oil series. The strata of the explored portion of the oil-yielding series of Baku are composed of grey, blue-grey, and green-grey clays; several varieties of sand that are grey when washed, but often darkly discoloured with oil when raised; and sandstones, many of which are more or less calcareous and sparingly fossiliferous. The Baku formations are supposed to belong to the Oligocene and Lower Miocene age, which gives to them a very modern (geologically speaking) origin.

Clays.—The clays, which are often interleaved by thin laminæ of fine sand, do not induce the same amount of interest as the sands, but still there are peculiarities attaching to some of these beds that render a description obligatory. Many of the clays of blue and green-grey tints are quite dry, and devoid of all traces of oil, although they are often fossiliferous and contain well-preserved shell remains; but other clays when split open reveal decided traces of petroleum along the cleavage planes, and possess an unmistakable odour. Such clays as the latter are generally known as gas or oil clays, the former term being applied to those which have an odour only, the latter designation being confined to such as contain visible traces of petroleum, and the presence of oil in such a compact formation as clay rather supports the view that petroleum has been formed in the stratum and not subsequently admitted. Clay possesses a peculiar affinity for oil, notwithstanding its well-known property of imperviousness to liquids, but such a closely built-up deposit could not possibly act as an extensive reservoir for petroleum, nor is such an impermeable substance likely to deliver up its absorbed contents very readily. Oil wells are sometimes stopped in clay, and do yield a production, but in most cases sand puts in an appearance and at once discloses the origin of the oil; in fact, it is extremely doubtful whether oil in moderate quantities is ever obtained from a clay stratum.

Some of the Baku clays are permeated with fine hair-like fibres, which, on closer examination, seem to be the veins of skeletonized vegetable matter, but perfect specimens of plants are rare, and the outlined impression is insufficient to indicate the species to which they belong. These fine carbonaceous particles might be taken, by a casual glance, to be foreign substances that have become contaminated with the strata in the bore-hole, but a close inspection will remove this delusion.

The Grosny clays more nearly approach marls in character, being, in most instances, highly impregnated with calcareous matter, and they have also suffered from the effects of a slight metamorphism and been altered in appearance.

Sands.—The number of distinct varieties of sand found in the Baku oil-bearing series is amazing, and the closer the subject is investigated the more complex does the origin of these appear. For the sake of convenience, the sands are divided into three or four classes by engineers connected with the industry, namely, water sands, gas sands (dry sands), and oil sands; but these terms are ambiguous, for one type merges by almost imperceptible changes into that of another, and the terms do not always divulge the true nature of the deposit. The ambiguity of this classification of sands becomes more apparent the larger the experience of the engineer, for oil is found in gas sands, oil sands are found dry, and it is not certain that oil is not sometimes struck in water sands.

Water Sands.—A coarse, sharp-grained, white sand is occasionally met with interspersed in the oil series, and as it is found to be, in nearly all cases, quite free from petroleum and full of water, it is described as a "water" sand. The term has been applied to a sand which is perhaps a "water" sand in more respects than one, for a careful microscopical examination will disclose the fact that most of the particles are more or less angular, and of a character much more nearly approaching sea-shore sand in appearance than any other variety found in the oil series. The majority of the grains are transparent, or nearly transparent particles of silicious material, such as a beach formation usually discloses. A "water" sand of the above description has been traced all over the Balakhany-Saboontchy-Romany plateau, and its presence serves as a very reliable datum line upon which to base the levels in different parts of the oil field. It is always full of water, and local experts formerly declared that this bed represented the end of the oil-producing series, and that nothing but water existed beneath —a view, the fallacy of which has recently been proved by the completion of productive wells that have been carried right through the water stratum. It is worthy of note that many wells so deepened have proved decisive failures because proper measures had not been undertaken to exclude the water, without which precaution it is useless to expect oil. This deep "water" sand is interesting in many ways, and will receive further notice when the other varieties of sand are being dealt with.

Gas Sands, Dry Sands, and Oil Sands.—The relation of gas sands, dry sands, and oil sands to one another is so intimate that it is really impossible to treat one without reference to the others—a difficulty which will be avoided as much as possible by having all under consideration at once. The three classes of sand which pass under the titles of "gas," "dry," and "oil" sands apparently belong to a type of a totally different nature to the already-mentioned "water" sands. An examination of any one of these under a microscope will disclose a peculiarity which will be found to pervade the whole; many of the grains will be found to be beautifully rounded. A large proportion of the particles are smooth spherical or spheroidal pebbles; in fact, their character at once suggests a wind origin, and all authorities who have examined samples immediately expressed this opinion. Recent geological investigations have proved many of the great sand and sandstone formations to belong to this class, and the sands wherein the oil lies preserved are evidently of a similar type. There are numerous qualities of æolian sands; some are extremely fine and are scarcely recognizable from clay when impregnated with oil, but are distinguishable as excessively fine blown sands (dust) when dried and examined microscopically; others are easily discovered to be sands, although very fine; whilst the coarsest varieties might easily be mistaken for fine water sands.

The dust, or finest sands are generally gas-producing, that is, they will be found to be darkly discoloured and highly impregnated with petroleum gas, which makes itself apparent by its odour when a consolidated piece of sand is broken. The term "gas" sand is applied to such varieties as possess these peculiarities; but the designation is ambiguous, for gas sands sometimes yield oil, and there is no clear distinction between these and "oil" sands. The largest supplies of petroleum are obtained from the coarser classes of sands, to which the title "oil" sand is given; but experience proves that oil is in no way confined to this description of sand, and that almost as prolific sources are occasionally encountered in the finer types. At one time, gas sands were always contemptuously passed during boring, and treated as unprolific; and it is only during recent years that local engineers have realized the close connection existing between the two types, and made use of their knowledge. The mere quality of compactness that characterizes the gas sands is a sufficient reason for assuming a less prolific nature than the coarser kinds, and in practice such is generally found to be the case. Nevertheless, there are numerous instances where 3000 to 4000 poods daily have been obtained after a prolonged bailing from the "gas" variety.

Although most of the æolian sands are impregnated with a certain amount of petroleum, such does not seem to be always the case, especially where the sands appear in thin laminæ, as occasionally happens in some parts of the oil field. The oil-bearing character of a sand is discerned immediately when it reaches the surface in a darkened and odorous condition, but not infrequently unexcluded overhead water disguises its nature to such an extent that a mere glance will not suffice to distinguish its class, and a more minute examination must be conducted. A white or grey, inodorous, unstained sand is often disdainfully rejected by a careless engineer as a water sand, when a microscopic examination divulges the fact that it belongs to the blown variety of sand, and, consequently, is not a water-bearing sand, but simply washed by contact with water. Many examples could be enumerated to demonstrate how perfectly grey sands, destitute of all petroliferous signs, have yielded a large production of oil on the exclusion of overhead water, which previously had unchecked communication with the bore-hole. In one case the boring contractor insisted upon designating a grey sand as "water" sand, which had been penetrated well within the limits of a recognized oil horizon, and on the completion of a cementation, at the author's request, the misnamed "water" sand gave over 4,000,000 poods of oil, yielding for a few months as much as 10,000 poods daily.

When a fountain is blowing vigorously, large masses of detached strata are released from the formations in the vicinity of the oil bed, and flung violently from the bore-hole, thus giving to the engineer samples of the ground much larger than any usually obtained from the well during boring. In some instances, large, compact pieces of dark sand are raised, through which fresh gaseous petroleum is disseminated to the extent of, perhaps, 10 to 20 per cent. of its bulk, which give to the student a correct idea of the appearance of the sand as it lies in its original state below; in other cases, large lumps of solidified sand (rock) are ejected, which exhibit fissures, from which petroleum slowly emerges for some time after ejection; whilst at other times, instead of masses of strata being cast from the well, a loose, flowing sand is discharged with the petroleum, which creates the impression that it never was in a solid condition, even in the earth. The change from loose, flowing sand to a compact oil sand, and thence to a hard sandstone, cannot be easily explained, although there seems to be undeniable evidence that the three types occur in the same zone within short distances. Calcareous matter is largely disseminated throughout the oil-bearing strata, and it has been suggested that the presence of this cementing material in variable proportions is responsible for the divergent characters of the sand. Foraminifera may sometimes be discovered amidst the particles of oil and gas sands, and in the sandstones large masses of some calcareous substance may often be discerned, together with numerous fragments of carbonaceous matter. Now, the amount of carbon fluctuates from a mere trace in some specimens to 15 or 20 per cent. by bulk in other cases, so that if this varies to such an extent, the proportion of lime could also vary, in which case the difference might be sufficient to account for the appearance of compact sand in one spot, sandstone in another, and loose sand in yet another place. Where oil sands of a compact description are perforated by the drill, the production is not usually very great. Where a bore-hole is bailed in rock, the production is even less, and rapidly falls off, although it will generally continue to yield moderately for years without giving any sand; but where the very loose sands are struck, on moderately new ground, phenomenal fountains and bailing wells often result, from which millions of poods of oil are secured, and thousands of tons of sand brought to the surface.

It will be seen from the foregoing that the percentage of oil contained in the sands varies according to their character. The rock may contain but 1 or 2 per cent., or even a fraction of 1 per cent. only. The compact sands may absorb anything from 10 to 20 per cent. of their bulk, and the loose sands may be permeated to the extent of 25 to 50 per cent. of their volume with petroleum.

That the Grosny oil beds are not impregnated to anything approaching the same degree as the Baku sands is shown by the rapidity with which a new well is exhausted in this field, and the impracticability of sinking several wells into the same source within a small radius. The compactness of the strata and absence of loose sands account for this failure, for neither can such strata absorb the same amount of oil, nor can oil be expelled to an equal extent, even when backed by a high gas pressure.

The main features that characterize the oil sands are those which indicate a wind origin, the existing storages of oil being nothing more than huge deposits of dust and sand blown from deserts and dry wastes that bordered the Caspian region at one time. The phenomenon is to-day represented by the loess of Europe, Asia, America, and the sand-storms of the desert, in both of which cases thousands of tons of arenaceous particles are driven annually into space, only to find an ultimate, undisturbed resting-place in some ocean-bed or other sheltered spot. Many regions around the Caspian are even now visited by similar storms, and there are at the present moment deposits in the Caspian Sea itself which must closely resemble the sands through which the Baku oil is disseminated.

One striking peculiarity connected with the oil sands calls for special mention, namely, the appearance in the beds of large numbers of hard, well-rounded nodules, to which it is very difficult to assign an origin. Many are evidently concretions of sand around a central object, from which, doubtless, originated the structure, for on splitting open the nodules with a hammer, they will often be found to contain a fairly large fragment of wood in a moderate state of preservation. The inferences to be drawn from the presence of these nodular concretions and other fossiliferous remains appear, however, in Chapter III., and will not be discussed here.

Distribution of Petroleum in the Strata.—No one who has studied the geology of the Russian oil fields will deny the existence of specially prolific petroleum-bearing belts or zones, separated by intervals of non-productive, or at least only gas formations, but consisting more often of dry beds, devoid alike of gas and oil. In the Saboontchy-Romany district no less than eight highly-productive belts have been discovered, in the Bibi-Eibat field five, and in Grosny five; and no one can say that deeper boring will not disclose the existence of still more. A comparison of boring journals will speedily reveal the fact that the strata are not deposited regularly, and numerous explanations are forthcoming to account for the erratic and irregular occurrence of the beds, the depth of which can never be stated with precision beforehand.

When boring a well, the engineer naturally makes special inspections and more careful examinations of the disintegrated material raised by the tools when approaching a well-known horizon; and in the entire absence of oil indications, or if in the opinion of the engineer there is enough water present to conceal the true identity of the strata, he may feel justified in cementing the well and excluding the water. In numerous cases wonderful producers have resulted from the judgment of the engineer who has been guided in his decision by some trivial detail that an inexperienced person would have failed to notice. Occasionally the oil sand is struck very near to the estimated depth, but at other times only a faint trace or nothing is found that would imply the presence of oil, so that one is led to inquire whether there is uninterrupted connection of the sands within a fixed zone, or whether continuity is broken.

There is great variation in the depth of oil sands, for whilst in some places they have reached a thickness of 50 feet, in other parts in the vicinity they have not exceeded a few feet, or have been quite absent. The difference in the depths of the sands could be explained by local variations of thickness and by folds of

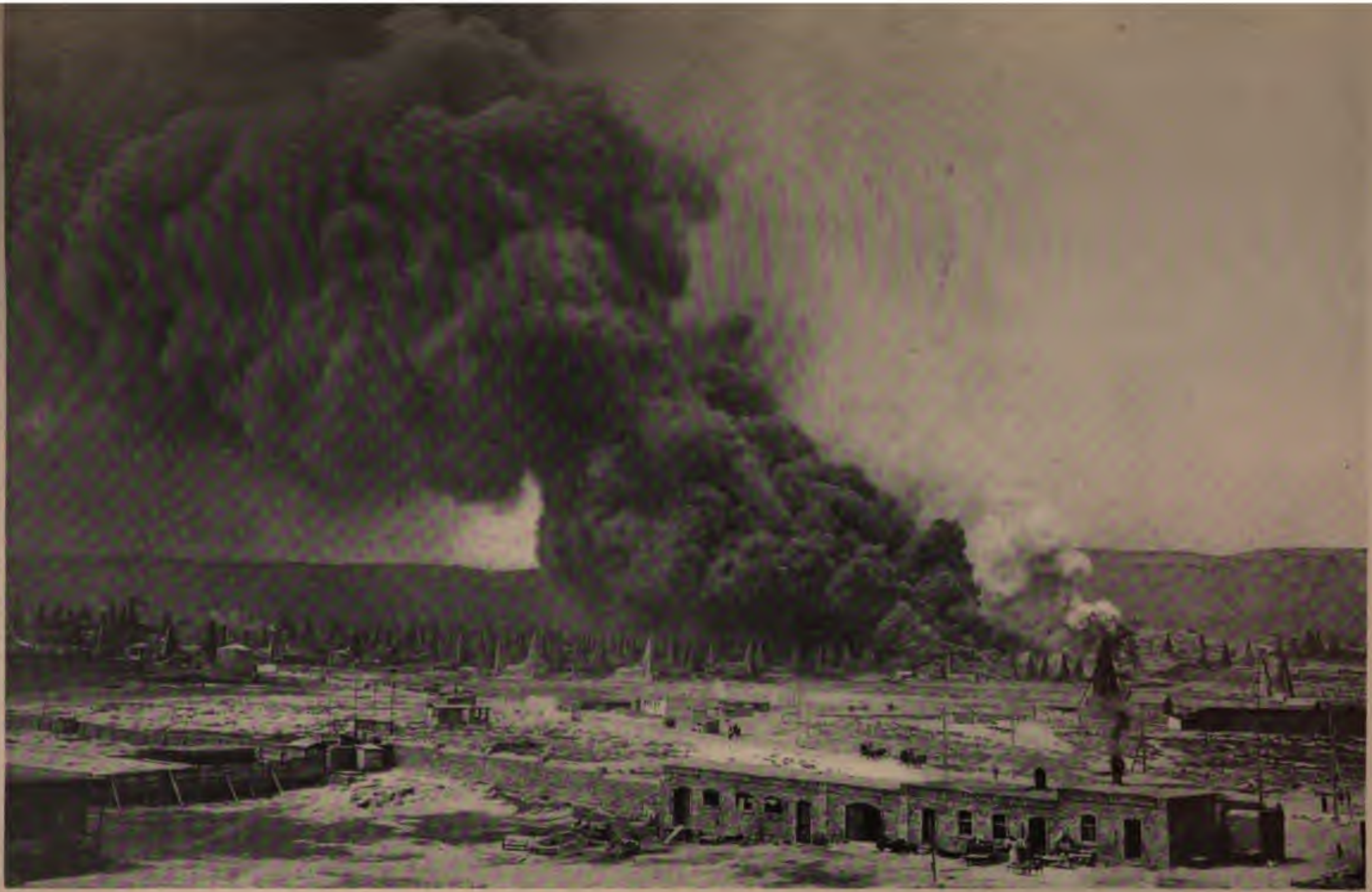

Fig. 8.—General View of the Bibi-Eibat Oil Field, showing a Fire on Plots 47, 48, and 49 B.-E.
(On the extreme left may be seen the wharves from whence the oil is despatched in barges to Blacktown.)

the strata and the perforation of the bore-hole cutting the bed at an angle; but as the underlying and overlying formations do not exhibit the same peculiarity, this explanation will not answer. A more acceptable exposition accounts for the irregular appearance of the oil sands by the existence of lenticular pockets, which swell out in one direction and thin in another, that may or may not be connected, although the latter is more likely, for reasons discussed later on.

The Russian Government has not undertaken a systematic geological survey of the district including the oil fields, and the duty of conducting investigations has naturally devolved upon one or two of the large firms of old standing, who possess a mass of valuable matter, collected over many years, that might lead to the solution of many doubtful problems if systematically classified. At present, the "lenticular pocket" theory offers an explanation for a difficult point, and introduces few dissentient factors of a condemnatory nature. That direct communication between the oil sands in the same belt is not always established is proved by the different specific gravities and levels of oil in two adjacent wells separated by only 100 or 200 feet, and in one peculiar case a single well gave oil with a specific gravity exceeding 0·890, whilst several other wells around, bailing from the same depth, yielded oil of a specific gravity never exceeding 0·875. Wells stopped in oil zones which do not show the least indications of oil or oil sand, often yield a large production of oil after a prolonged bailing, or exclusion of overhead water—a singularity which supports the view that oil exudes from a side receptacle, or rather from one of the lenticular pockets already described. If a well strikes direct on to a virgin pocket, a fountain or big producer may immediately result, but if no simple connection exists with the pocket, the gas will not break down barriers that divide it from the bore-hole until the pressure in the well, created by the collection of water, is reduced by bailing, or a process of cementation. Additional evidence of the non-continuity or absence of free intercourse between different sections of the same bed is found in the periodical change in the production of a bailing well—a peculiarity which no oil engineer can have failed to observe. A well may be bailed for months or years without any important change, except, perhaps, a lowering of level, when, without any warning the level rises, and possibly a periodical fountain occurs, and the well gives for a time two to three times its normal output. In cases of this kind it is difficult to assign any other reason than the fracture of a barrier which had for a time excluded communication with the oil being bailed from the well. Of course, the term "pocket," when applied to this subject, must not be understood to mean a small local deposit, for millions of cubic feet of petroleum are abstracted from many of the beds to which this convenient title has been attached. The approach of a fountain, in a well that periodically flows, is sometimes indicated by a change in surrounding wells bailing from the same source that are not of a flowing description on account of some peculiarity in their position or defect in their construction. For example, only recently, the owners of a Bibi-Eibat well, which spouted at intervals, and yielded prodigious volumes of oil, were invariably apprised of approaching activity by a neighbouring proprietor, who observed a remarkable, temporary improvement in his well—less than 100 yards from the first—a few hours before the flowing commenced. All adduced evidence concerning the subterranean movements of oil only confirms the conviction that the oil beds do not freely communicate, although they may not be parted by obstacles of an insuperable kind. In one example illustrating the point at issue, the water-level of a well prior to cementing stood within 150 feet of the surface; there were signs neither of oil nor of gas, and the ground raised did not show the slightest trace of petroleum, yet, after excluding the water by cementation, the well filled with oil, and although stopped in a stratum where oil was neither expected nor suspected, yielded from 500,000 to 1,000,000 poods (2,000,000 to 4,000,000 gallons) per month for many months, and gave over 10,000,000 poods (40,000,000 gallons) in a little over two years. Sand was bailed and thrown out by periodical fountains in abundance, but quite dissimilar to any met with in the boring, except, perhaps, in insignificant quantities as are commonly found in all wells, and during the first three months its quantity exceeded 5000 tons, and the services of from ten to thirty labourers were needed, night and day, to clear it away from the mouth of the well.

Movement of Oil in Channels.—The area affected by a big producing well is considered in the next paragraph, but it is deemed expedient to describe firstly a feature which leads to the irregular occurrence of the oil even when the oil-bearing sand itself is struck. In actively exploited areas, wells may often be carried into a rich oil sand, from which other borings are drawing a large supply of petroleum within a few yards, without any paying production resulting, even after weeks and months of testing. At first sight such a condition appears impossible, but it is an indisputable fact, recognized by all who have long been associated with the practical work on the Baku oil fields, that the striking of a good well or a series of large producers attracts the stream of oil towards that region, and, instead of decreasing the immediate value of that area, its tendency is to enhance it greatly. The large quantities of oil and sand which in a comparatively undisturbed area are impelled towards a new well by an almost irresistible gas pressure, appear to carve out grooves or veins which ramify in various directions, and act as feeders to the principal points of abstraction. When the initial high pressure of the gas has found relief, and but a small pressure remains, the oil cannot readily be induced to flow in other channels, and unless a new well located alongside a producer happens to intercept one of the feeders, in many cases nothing, or very little oil will be obtained. A very intelligent, old Baku boring-master compared the oil beds of the oil fields to the human body, where the capillaries supply the veins, which in turn feed the heart, which, if perforated, drains the body.

A well in the Saboontchy district, about 1200 feet deep, yielded a steady, continuous production of 2000 poods daily, but a new well which reached the same sand at an equal depth failed to supply more than one-tenth of this amount, viz., 200 poods, although not more than 50 feet away, and repeated trials furnished no more. Such examples are common in districts already moderately well drained, where there is a low level; but, of course, such effects could not be reasonably expected where the gas-pressure is still very strong, although cases are not unknown. In abnormally prolific territories, where the confined gas exerts a terrific pressure, any well sunk within a large radius of a lenticular bed would be productive, through infiltration of gas and oil in veins or seams of porous strata. Many convincing illustrations could be enumerated, proving that rarely can two wells be completed at the same depth, near together, on drained areas, without the first boring securing and retaining its character as the best producer.

In the Balakhany oil district, where the oil is heavy, and the gas has nearly all escaped from innumerable wells, the concentration of the petroleum towards old producing areas is very marked, and whilst old bailing properties, which have for many years yielded a moderate payable production show little or no fall-off, new lands interspersed between these are almost valueless and give practically no output when new wells are sunk. This is additional testimony of the movement of oil towards spots where immense quantities of sand have been removed by bailing, creating areas of low density into which the petroleum, no longer assisted by a gas pressure, percolates by gravitation. In one case, a new well bored in the Balakhany district was a distinct failure, for stratum after stratum failed to yield even a mean production, but an old well which had been bailed for many years before abandonment, gave, when cleaned out, the extraordinary production of 2500 poods a day for more than a month, and then only fell off by degrees to 400 poods daily.

Curious instances of periodical deviations of channels could be related, of which the following is a characteristic example. A number of wells within a small radius, belonging to several proprietors, were bailing from the same oil source, but one or two of them were not properly cemented, and admitted a large quantity of water into the oil stratum. The consequence was that several of the bore-holes always gave water whilst the others yielded oil, but if a water producer were allowed to stand idle for a month or two, the water was diverted to a well formerly giving oil, and, on recommencing to bail, oil was always obtained. After a month's or two months' bailing of oil, water reappeared and entirely displaced the oil, necessitating another prolonged stoppage, and this repeated changing continued for years.

The attitude of the Russian Government, who are the owners of the greater part of the oil-producing lands in the Caucasus, not excepting Baku, in leasing out ground, for the exploitation of oil, in blocks separated by strips of land reserved for future auction, has led to a greatly diminished quality of the intervening plots, and whilst such a system has its advantages, it leads to a greatly reduced value of the unoccupied portions. These deferred plots are already impoverished by the removal of great quantities of oil from wells on their boundary, but, for reasons already stated, their worth is still further lessened, and future applicants should be modest in their expectations, and not base their offers on the results of adjacent exploited sections. When the gas has to a large extent been liberated, the sand is neither so easily impelled towards the wells nor raised in such quantities as on virgin lands, so that the area of less density (not exactly cavernous) so conducive to a large producer, wherein the oil from the surrounding strata collects, is absent. Occasionally unexpected fountains occur on well-exploited areas, due certainly to the perforation of a bed totally isolated from the surrounding strata—an eventuality that causes consternation to the unprepared proprietor who has no storage provision.

Area influenced by a Producing Well.—In new prolific areas, such as parts of Saboontchy, Romany, and Bibi-Eibat, a direct connection has been traced between spouting wells separated by as much as 600 feet, the cessation of flow in one leading to the immediate activity of another. From ordinary bailing wells it is impossible to derive any useful information by comparisons of levels, temperatures, specific gravities, etc., as all of these are affected by the amount of water gaining admission, the quantity of gas, size of well, age of well, rate of withdrawal of liquid, presence of plug, and numberless other details acting singly or jointly. All attempts to trace a connection between a number of wells draining a single oil source have resulted in failure, and the more attention this problem is subjected to the more perplexing it appears.

A simple calculation with a few assumed factors will perhaps contribute more useful information than a mass of conjecture on this question, and give a means of realizing what a large area must come under the influence of a great Baku oil well. For the purpose of the calculation, let the oil source be assumed to be 20 feet thick, on an average (a very reasonable figure), and contain, also on an average, 25 per cent. of its bulk of petroleum, then for each million poods of oil extracted, no less than 2,666,666 cubic feet of oil stratum have been affected. A well, therefore, which has produced only *one* million poods of oil, has, on the above assumption, caused the displacement of oil over an area of 133,333 square feet, or 3 acres, and by applying the formula $r = \sqrt{\frac{\text{area}}{\pi}}$, it will be found that this is equivalent to a radius of 207 feet around the bore-hole. Ten million poods, which is not an uncommon amount to obtain from a single well, would drain more than 26,000,000 cubic feet of stratum, that is, an area of over 30 acres, or 11 dessiatines, equivalent to a radius of 650 feet round the bore-hole. Twenty and even thirty millions are sometimes extracted from a Baku oil well, when it is highly probable that, for a distance around, at least, the depth of the sand is greater and the percentage of oil higher, but if the assumed figures are doubled (the bed being 40 feet thick, and the oil 50 per cent.), the extensive area drained, and the still greater expanse influenced, are amazing.

The speed with which petroleum is expelled from its source cannot fail to draw an exclamation of astonishment from a person who witnesses a great Baku fountain for the first time, for sometimes 600,000 cubic feet of oil are ejected in 24 hours, or at the rate of over 400 cubic feet per minute. One day's output from such a well would fill a reservoir 84 feet square to a depth of 84 feet, and the weight of petroleum would exceed 14,000 tons. Such a rate of expulsion, on the basis of the 50 per cent. proportion, would mean the displacement of oil from over 1,250,000 cubic feet of ground in one day, or the drainage of an area of three-quarters of an acre, on the supposition that the bed was 40 *feet deep* and contained 50 per cent. (by bulk) of oil, whilst the area affected would probably be quite three acres.

The oil from fountains is commonly accompanied by an equal bulk of sand, large numbers of stones, and the liberation of millions of cubic feet of gas which becomes disengaged from the oil on its exit from the tube. A recent Bibi-Eibat spouter on plot No. 29 gave as much as 10,000 tons of oil and 10,000 tons of sand in a day, and in a few weeks yielded, in addition to several million poods of oil, no less than 1,700,000 cubic feet (85,000 tons) of sand; an amount which will be better appreciated when it is realized that this quantity of material would raise the natural level of the ground on 1 dessiatine nearly 14 feet, or cover an acre of land to a depth of 40 feet.

In the early days of the oil fields, when it was the practice to shut down flowing wells, a connection was frequently traced between widely separated wells—a result that caused controlling valves to fall into disuse, for oil producers who closed their spouting wells to allow the market to improve, usually saw their plan frustrated by the appearance of a fountain on a less considerate proprietor's adjoining property, where a bore-hole perforated the same source. Reopening a closed well nearly always induced renewed activity, in which case the neighbouring fountain ceased to flow.

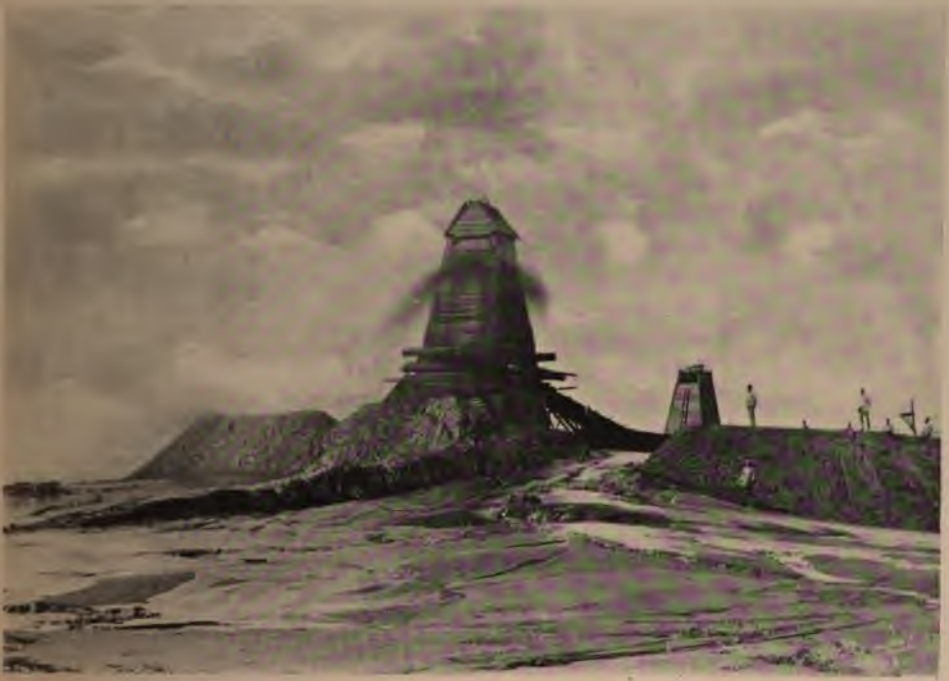

Fig. 9.—A Baku Spouter, showing Derrick almost buried in Sand ejected by Fountain.

Disclosures of this character prove that underground communication is uninterrupted for long distances, which in its turn demonstrates the continuity of the oil stratum, although, perhaps, of variable depth, and disproves the assertion, sometimes made, that the irregular occurrence of the oil bed is due to the presence of local faults or to an inclination of the strata.

Effect of Water on the Production of Wells.—Many of the great Baku producers of more than average fertility have been the sequel of a cementation where all signs of oil were conspicuously absent, and where the previous water-level was very high, and the question arises whether the relationship is not more than a mere coincidence, and whether the water does not itself exercise a potent influence in completing a connection between the oil and the well, or act as a medium for the movement of oil. Suppose a bore-hole to be sunk to a depth of 1400 feet into an oil zone, without the water, which stands near the surface, being excluded, a simple calculation will show that the pressure exerted on the stratum at the bottom of the well will be between 500 and 600 lbs. per square inch. Now, if the location of the well falls within the precincts of a supersaturated lenticular bed, it is possible that a little water might, by degrees percolate through the less impervious seams in the strata and advance, aided by the high pressure, to the pocket itself. The result of such an action would be the creation of a direct channel with the well, otherwise unattainable, but no oil would be obtained until the opposing water pressure was relieved by a process of exclusion. The subject is an abstruse but interesting one, for if oil sources can be opened and the movement of petroleum facilitated by admission of water, it will be to the interests of oil producers to delay the exclusion of water, in some districts, to a late period. The effect of water in opening up oil sources may be beneficial in districts where the oil lies in very irregular and far-extended pockets, for it is strange that where there have been dry wells in such areas they have remained dry, or nearly so, the oil only percolating very slowly into the well, and where they have been full of water they have eventually been full of oil.

Such a peculiarity as that described could, of course, only be possible on virgin or slightly exploited areas, for if water were admitted to partly drained beds, millions of gallons might be absorbed by the sand prior to exclusion, and months of bailing might be necessary before oil was afterwards obtained.

Once or twice phenomena which illustrate this subject have occurred in Baku, one of which happened in 1902, when an exceptionally strong fountain was blowing in the Bibi-Eibat oil field, which ejected such volumes of oil that there was no storage accommodation, and considerable quantities overflowed all the adjoining plots. The stream of oil at length reached a depression at the bottom of which was an old disused well, long abandoned, and down this large volumes of petroleum flowed unchecked. To the pleasure and surprise of the owners, the well speedily developed into a fountain, and played continuously for several days, during which time it is estimated that much more oil was discharged than had been admitted. The action was somewhat similar to that described by the inlet of water. The entering petroleum was freely absorbed by the drained sand, wherein it traversed the old channels, and, after a time, the pressure and commotion occasioned in the source led to the opening up of undrained ground, which was eventually so excited that a reaction set in, and the gas and oil, liberated by the agitation, forced an outlet and caused a fountain. An equal volume of water, admitted at the same velocity, might have opened up the same undrained beds; but the water itself would have formed a plug dense enough to stop the oil from reaching the well, and only prolonged bailing, or lengthy testing with an air-lift pump, would have disclosed the results of the trial.

Many of the oldest boring-masters in the oil fields emphatically insist that a proportion of water with the oil does improve the life and production of the well; and there is, without doubt, much truth in the assertion, for in most of the best Saboontchy, Romany, and Bibi-Eibat wells, the percentage of water raised amounts in the aggregate to from 20 to 40 per cent. A little water in the oil stratum (quite distinct from that running into the well from imperfect exclusion) has the effect of increasing the fluidity of the oil, by dilution, and induces—especially in the case of heavy oils, when the friction is enormous—a more constant stream towards the bore-hole, and in cases where the gas pressure is *nil*, and the flow towards the wells is caused by gravity alone, significant benefit is derived from such contamination.

Best Position for Lining Tubes in a Well.—Having studied the peculiar conditions surrounding an oil bed, it is not, perhaps, quite out of place to mention here a few of the considerations that influence the engineer in deciding upon the best position for the lining tubes when an oil source has been penetrated. Conflicting opinions are held as to the correct situation for the shoe of the lining tubes; but in this, as in other matters connected with the oil industry, the engineer must exercise his individual discretion, and be guided by the particular conditions which present themselves on the plot where the oil is struck.

If a fountain commences to play directly the oil ground is perforated, the question is at once decided, as nothing further can usually be done, and the tubes must remain where they are. On well-drained properties, where the gas pressure is very low or entirely absent, the lining tubes must be carried deeply into or nearly through the oil stratum in order to get sufficient depth of oil to bail from, for on such land the oil slowly exudes from the sand, and its level, on standing, corresponds with, or is slightly less than, the level of the oil-bearing bed.

On virgin ground, or where a high level and strong gas pressure are known to exist, the best plan, theoretically, is to give the tubes a deep immersion, and secure the full useful benefit of the gas pressure; but in practice this situation has the disadvantage that a portion of the casing is practically suspended in a loose stratum, and it is forced out of the vertical by any slight movements of the sand. Such a position seriously endangers the safety of the casing, for landslips or cavings will carry the lower part of the tubes to one side, and lead to fracture or damage of some sort. If a hard material lies immediately above the oil stratum, a very substantial support is given to the tubes by stopping them at this point; but even then there is the constant risk of cavings from impermeable or hard ground taking place and impeding or excluding the inlet of oil.

On extensively operated plots, when there is still sufficient oil left to impart to the ground a fluid character, and where many wells are bailing within a small radius, there are frequent movements of strata, and the casing of wells is constantly being swept to one side and broken; in fact, in some fairly prolific congested districts, the presence of the oil to-day is entirely due to the prevalence of accidents, for no new well can be bailed more than a few months without a disaster, and the land would have been drained years ago but for the short life of the wells. There are no means of preventing accidents of this nature, which cause bitter disappointment to the engineer and owner alike, and the risk can only be minimized by observing ordinary caution in the management of the wells.

One large firm, which is very successful in its boring work, has a system of engaging the best boring contractors to explore its properties, by carrying down wells to a great depth and passing through all oil-bearing ground of whatever quality until further progress is checked either by a rising plug or the advent of a fountain; then only is the well accepted from the contractors. On new, rich properties this plan has answered admirably, and a very big output has, in most cases, been the result of this ambitious scheme. From wells completed in this manner on the richest parts of the Saboontchy field, 15,000,000 to 20,000,000 poods of oil have been obtained, which was not, however, the product of one stratum, but of several, for it was found that after the deepest source had yielded for a time, the tubes always collapsed at a higher oil zone, which next yielded a large production, or perhaps a fountain. A second, third, and even fourth collapse may follow in succession at other sources, each in turn augmenting the total output of the well by some millions of poods; and there is one example, at least, where the tubes collapsed in five distinct oil formations in succession, each fracture being accompanied by a considerable augmentation of oil.

The points at which the tubes will become fractured can be approximately foretold by consulting the boring journals; but the collapses do not always occur in the direct sequence, for the first damage may take place at one of the upper sources, and close securely two or three formations, a misfortune which can neither be foreseen nor prevented, even if suspected.

In a large number of cases abnormally prolific wells have been proved to have drawn their supply of petroleum from two or several oil sources, simultaneously or in rapid succession, and many other enormous producers, recorded from time to time, owe their origin, no doubt, to the union of the product from several strata, either unconsciously or purposely passed in the boring.

Collapses in the Baku oil fields are dependent, it will be seen, upon powers over which the engineer has no control, and, whatever the quality of the work or the position of the tubes, there is the constant dread of a mishap which will, in the space of a few minutes, undo the labour of a year. In Grosny, landslips are rare, and consequently the tubes only occasionally get fractured.

Amount of Petroleum stored in Baku Oil Strata.—When an attempt is made to estimate the quantity of petroleum stored in the sands underlying the apparently barren wastes of the Apsheron Peninsula, one arrives at strings of figures which can only convey a meaningless idea in themselves.

The Balakhany-Saboontchy-Romany oil field is, without doubt, the richest patch of oil-bearing territory of moderate extent that has ever been discovered, although it is likely to be rivalled, if not surpassed, by Bibi-Eibat. The total area of the exploited region scarcely reaches 4 square miles, but the borings are yearly extending outwards, and adding more proven territory to the now-recognized oil land. Carefully compiled statistics referring to the Baku oil fields have only been collected since the year 1892, so that no very reliable information is procurable as to the output, number of wells, depths, etc., previous to this date.

Between the years 1862 and 1892, collected particulars drawn from various quarters show that at least 1,000,000,000 poods of oil were abstracted from the Balakhany-Saboontchy plateau; and as, during this period, millions of poods ran to waste over the surrounding fields, and other millions were left to evaporate in huge lakes, or were disposed of by burning, it must be assumed that this figure represents a low estimate of the extracted petroleum. These oil fields were also worked in a desultory manner hundreds of years before the Russian occupation, and only since 1872, when the monopoly granted to Meerzoeff was abolished, has the industry expanded. From 1892 to 1902, official data show that 4,200,000,000 poods have been raised, which, added to that previously extracted, makes a total of 5,200,000,000 poods, or, approximately, 3,500,000,000 cubic feet of petroleum from an area, now only partially drained, not exceeding 4 square miles. This stupendous quantity of petroleum would fill a reservoir equal in area to the oil field to a depth of 31·5 feet; and if an average capacity of 25 per cent. of its bulk of petroleum is assigned to the strata, this is equal to a depth of 126 feet of prolific ground over the entire district.

The present annual yield of the Balakhany-Saboontchy-Romany plateau exceeds 500,000,000 poods; there are still large plots interspersed amidst the richest properties which have never been touched by the drill; in some regions the deep strata lie still unpenetrated, and it would not be a too sanguine statement to place the future production of this field at another 5,000,000,000 poods, which brings the total quantity of oil up to 10,000,000,000 poods, and increases the depth of the supposed lake of oil 4 square miles in extent to about 63 feet. On the supposition that the productive formations contain 25 per cent. of their volume of oil, the depth of oil-bearing ground rises to 240 feet, which, if divided equally between the eight known oil horizons, gives each oil zone 30 feet of prolific ground.

The most recent investigations of the flow of the River Thames made by the chief engineer to the London County Council, Mr. Maurice Fitzmaurice, show that the average daily discharge, gauged at Teddington Weir, is 1,110,500,000 gallons. Now, the oil already extracted from the Balakhany-Saboontchy plateau would furnish a stream equal in magnitude to this for twenty days' incessant flow, day and night, and the present yield of petroleum from this small district would keep a pipe nearly 2 feet 3 inches in diameter running constantly at a rate of 3 feet per second all the year round. It seems almost incredible that this volume of fluid could be recovered from such a small piece of land, and the problem of its origin is not simplified when it is asserted that the evidence available discourages the view that attributes the presence of such quantities to the location of huge stores of oil on the slopes of the anticlines, which are impelled upwards by gas or water pressure to replace the abstracted oil.

The monetary value of this patch of almost waste ground, situated in the centre of the Apsheron Peninsula, can only be appreciated when figures are prepared. Until the first fountain was obtained by boring, the price of crude oil stood at 45 copecks a pood, but the value dropped immediately to 5 or 6 copecks, and did not exceed 10 copecks for many years; but in 1900, when the annual production of the peninsula reached 600,000,000 poods, the price had risen to 16 copecks per pood. If an average price of 8 copecks is taken, the value of the oil raised from the Balakhany-Saboontchy-Romany plateau is about £42,000,000 * (416,000,000 roubles), or more than £16,000 per acre (over 40,000 roubles per dessiatine), so that if the estimated figures of production approach the truth, the value of oil secreted in this mere fragment of annexed territory is not less than £80,000,000, or over £30,000 an acre. As there are doubtless other places on this deserted territory equally rich, the stupendous value of these reported valueless regions, annexed by Russia with scarcely a murmur from other countries, can be realized.

The only ground yet exploited which will compare with the Balakhany-Saboontchy field is a low-lying bay surrounded by hills, in a semicircular form, about 3 miles due south of Baku, which is known as the Bibi-Eibat oil field. The exact value of this field has not yet been conclusively established, as it has only during the last few years been extensively worked, but the results so far attained appear to show that it will be quite as prolific, if not more so, than Balakhany.

One plot of 10 dessiatines (27 acres), held by Mr. Tagieff for many years, has the reputation of being the richest slice of oil-bearing ground the world has ever known. This property, which was purchased from Mr. Tagieff, in 1897, by an English group of capitalists, and floated in England as the Russian Petroleum and Liquid Fuel Co., with a capital of £1,000,000, has yielded, between 1896 and 1903, 250,000,000 poods of oil, and is still producing at the rate of about 30,000,000 poods annually. The oil abstracted in this period alone would fill a reservoir equal in area to the property 152 feet deep, and its value, calculated at 8 copecks per pood, is over £2,000,000, or £75,000 from each acre of land.

Previous to the year 1896, the plot produced at least 125,000,000 poods of petroleum, so that the total minimum output from these 27 acres of land has been 375,000,000 poods; sufficient oil to fill a tank equal in area to the property to a depth of 228 feet. The value of the oil, calculated at 8 copecks per pood, would be about £3,000,000, and the land has yielded over £110,000 per acre. In this exceptional example the property was completely isolated from other exploited ground, and until 1900 no surrounding plots were leased to other firms, so there need be no hesitation in saying that much of the oil was drawn from a long distance around.

Another wonderful property is No. XX. Bibi-Eibat, held by Zubaloff, which has produced at least 250,000,000 poods of oil from an area of nearly 10 dessiatines, and since 1896 the yield has been 130,000,000 poods. Romany furnishes some rich examples in plot No. 103, which has yielded to its proprietors, Messrs. Mantasheff and Co., 106,000,000 poods of oil since 1896;

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* A correspondent of the *Daily Chronicle*, in January, 1903, stated that the total value of gold extracted from the Rand mines (South Africa) amounted to £81,000,000, a sum that is less than double the value of oil extracted from 4 square miles of Baku oil ground. It would be interesting to compare the value per acre.

and plot 38, from which the Caspian Black Sea Co. has raised 150,000,000 poods of oil since 1896. One of the most wonderful plots of recent years is No. III. Saboontchy (No. 13 on maps), which has yielded an average bailing production of 3,380,000 poods of oil per annum per well.

In neither Bibi-Eibat nor Grosny has sufficient exploitation been conducted to estimate the quantity of oil dispersed amidst the oil-bearing strata.

Geological Conditions necessary for the Reception and Preservation of Petroleum.—The first condition essential for the storage of petroleum is a porous stratum in which it can accumulate; and the second necessary condition is the presence of an impervious stratum overlying the oil bed to prevent the displacement of the oil by water, and to stop the escape of petroleum gas which exercises an important influence on the exploitation of mineral oil. The first condition is inevitable if the formation of the petroleum is the result of decomposition of organic matter contained in the stratum, for the oil simply takes the place of the original substance; but upon the degree of porosity depends the commercial value of a district, as this makes all the difference to the area that can be drained by a single bore-hole in a definite time. The second condition is usually responsible for the existence of petroleum, for without the impervious covering, oil would probably never have been formed, or, if it had been, it would have escaped.

It is the amazing porosity of some of the Baku oil sands that has led to such phenomenal producers from these fields; 200, 300, and 400 cubic feet of petroleum, mixed with nearly an equivalent weight of sand, and hundreds of cubic feet of gas being ejected per minute from a bore-hole, without any artificial assistance.

Many oil experts attach considerable importance to a third condition, which they assert is necessary for the aggregation of large volumes of petroleum, viz., an anticlinal structure of the strata. The pressure of the oil and gas in some of the American oil fields is attributed to pressure of water which has collected in the synclines, displaced the original petroleum, and forced it into the summits of the anticlines, where it accumulates under pressure. In Russia, it seems unlikely that the anticline is essential for the aggregation of large quantities of petroleum, although indirectly it plays the important part of bringing the oil beds to within a workable depth from the surface—a characteristic usually absent where the synclines occur, on account of superincumbent beds of a later age.

It has been explained that the oil lies secreted in lenticular pockets which do not freely, if at all, communicate one with another, although, under intense excitement and after removal of much sand, oil, and gas, such as is occasioned by the perforation of some strata by a bore-hole, the barriers separating distinct beds may be broken down and communication established. Under natural conditions it is extremely doubtful whether the oil-bearing sands do sufficiently communicate to allow such movements of gas and oil as the anticlinal theory renders a necessity; indeed, such phenomena as those described on pages 49 and 51 discredit such a supposition. No relation exists between the sea-level and the levels of the oil in wells, for both on the Balakhany-Saboontchy field and at Bibi-Eibat, lying on the shores of the Caspian, the petroleum at times shoots up 200 to 300 feet above sea-level, and at other times its level is as low as 1000 feet below the sea. Rarely do the levels of oil in wells correspond, although the bore-holes may be at the same depth and draining the same oil zone, and even when wells stand idle for days or weeks, during which time equilibrium could be established, the levels of liquid nowhere correspond.

The pressures encountered in the Russian oil fields are almost certainly due to the presence of gas held in solution in a very compressed state by the petroleum until relief is afforded by a bore-hole penetrating the source. The rapidly evolved gas which follows a relief of pressure, carries with it in its movement sand, oil, and stones, and ejects them from the well in the same way as the contents of a champagne bottle are expelled on releasing the cork, or a seltzergene flows on opening the tap.

There is no evidence in the Russian oil fields that the synclines are not as productive as the anticlines, and the author is inclined to believe that the synclines corresponding to the anticlines of both the Balakhany-Saboontchy plateau and the Bibi-Eibat oil field would be found to be as rich in oil as the anticlines, if they could be reached. On both the Saboontchy-Romany and the Bibi-Eibat oil fields, wells which have penetrated the oil beds on the furthest removed points of the anticlines yet tested, where the strata descend at a sharp angle, have proved to be just as prolific as those disposed along the apex of the anticline. It is obvious that were attempts made to exploit synclines at shallow points near surface outcrops, failure would inevitably result; but were a gentle, unbroken, synclinal, and anticlinal fold to be tested side by side, little difference in yield would be likely to result if the strata were similar to those of the Apsheron Peninsula. Sharp anticlines, where the beds are highly inclined and the strata outcrop at the surface of the ground, would naturally be unlikely to furnish abundant supplies of petroleum, as the gas for a considerable depth would have escaped, and the potential energy, which is so valuable for expelling the oil from its source, would be lost.

There is one very important reason for assuming that the petroleum in the Balakhany - Saboontchy and Bibi - Eibat anticlines was produced where it is now found, and not subsequently admitted from other sources. In Chapter III. mention is made of a recent discovery which was made during the investigations for this work (see pages 83 and 84), whereby it may be possible to distinguish, in most cases, the difference between petroliferous strata wherein oil was produced and that which acts merely as a reservoir for the storage of petroleum produced in another place, and forced by gas or water into its present situation. In the Baku oil fields there is strong evidence, if the test is proved to be always satisfactory, that the oil was produced in the strata where it is now found, and was not admitted from other positions — a fact of considerable importance which has never before been recorded, but a result which serves to confirm the views expressed in this work.

CHAPTER III.

THE ORIGIN OF PETROLEUM IN THE CAUCASUS—PHENOMENA ATTENDING ITS DISTRIBUTION.

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The Nodules.—Formation of calcareous sandstones—Manner in which nodules were probably produced.

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Marine Siliceous Organisms.—Possible presence of diatoms or other silica-secreting organisms in Baku oil sands.

Phosphates.—Prevalence of phosphates in oil strata—Importance of the discovery of phosphates upon a theory for the origin of petroleum.

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CHAPTER III.

THE ORIGIN OF PETROLEUM IN THE CAUCASUS—PHENOMENA ATTENDING ITS DISTRIBUTION.

The Caucasus.—Before discussing the origin of oil, it would, perhaps, be proper to describe the salient features of the petroliferous districts, and particularly to note what relation the Caucasian range of mountains and the Caspian Sea bear to the oil deposits.

The Caucasus is an example of a recently elevated range of mountains—using the word recent in a geological sense. It is at least newer than the petroliferous beds occurring in or contiguous to it, for productive oil-bearing strata are found at a great height on its flanks. At Grosny the oil is obtained from the summit of a range of hills, where the anticline is very acute, and the prolific strata only approach the surface, to a workable depth, within a very narrow width. Fig. 9*a*, shows the enormous area covered by petroliferous strata, which crop out at intervals over practically the whole base of the Caucasus, but, of course, only lie at a depth that allows of profitable boring, *i.e.*, are prolific enough from a commercial point of view, over a comparatively small fraction of the whole. The enormous deposits extend beneath the sea (from the Apsheron Peninsula), where it is impossible to estimate their value or extent, and reappear in the Trans-Caspian provinces, which are as yet only very imperfectly explored. It has been estimated that the Russian oil fields cover an area of no less than 14,000 square miles, but the approximate value of this immense slice of territory has never been ascertained, for, until 1903, the whole of the Russian oil has been extracted from an area of less than 20 square miles, and all but a mere fraction of the total quantity has been raised from less than 10 square miles of land. There are, however, enormous tracts of tested oil-bearing ground which the Government is holding in reserve, and will not yet allow to be worked.

The deductions to be drawn from the above observations are—

(1) That the oil-bearing beds are older than the Caucasian range, and therefore the formation of petroleum was antecedent to, and quite independent of any terrestrial phenomena resulting in the upheaval of the Caucasian mountains.

(2) That an anticlinal structure which does not result in fracture of the beds (as in Baku, Bibi-Eibat, etc.) is beneficial to the winning of oil—by bringing the petroliferous strata to a workable depth from the surface, and perhaps by facilitating the aggregation of gas and oil in some cases—but one which fractures the beds and exposes their edges (as in parts of the Caucasus) is detrimental.

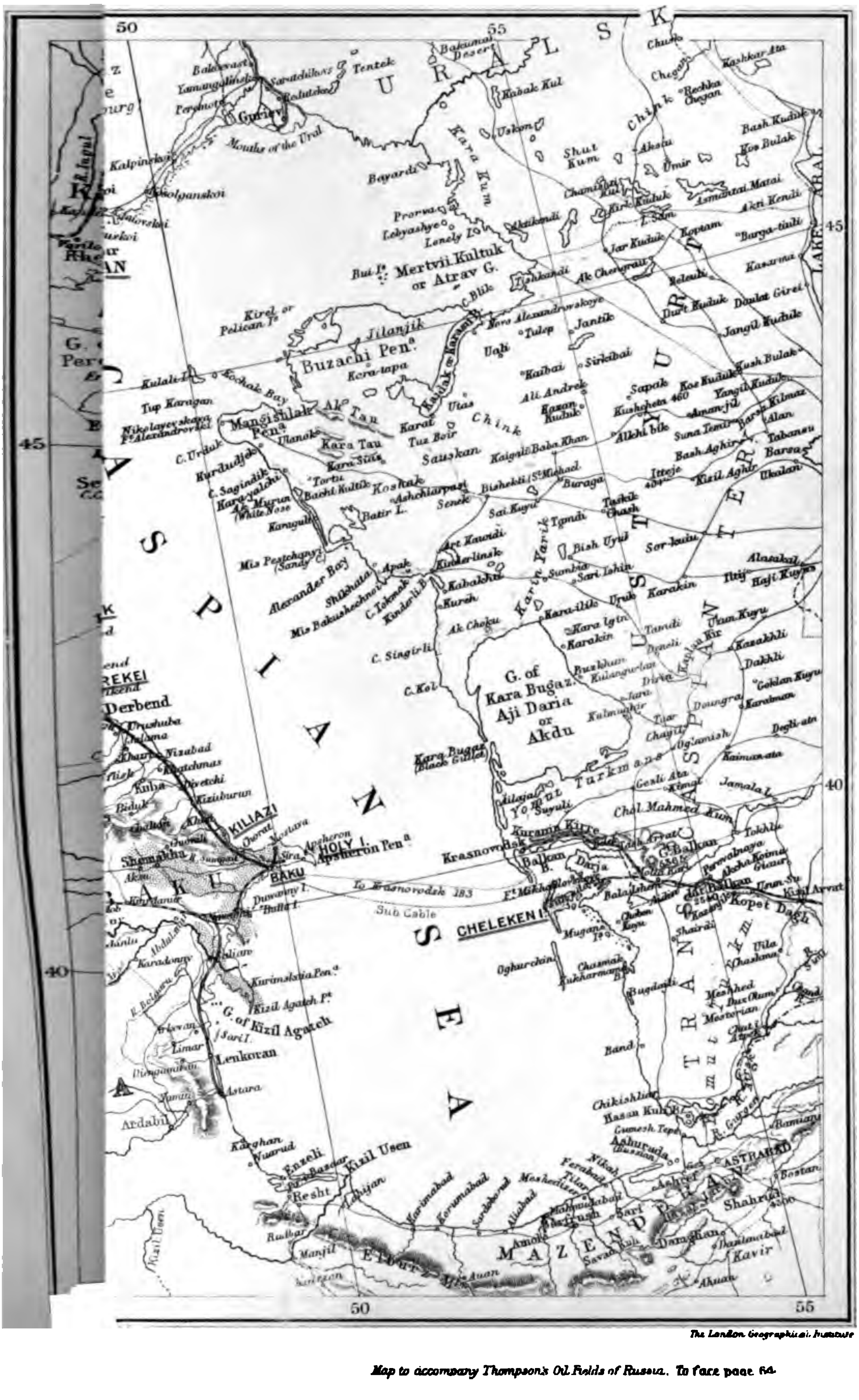
(3) That the synclines may be equally prolific of oil with the anticlines, but

they lie at a much greater depth, and are consequently quite useless, in most cases, for the remunerative extraction of oil.

(4) That for a fluid such as gas, under enormous pressure, beds of the same relative age would not be so perfectly independent of each other as the erratic occurrence of oil would seem to indicate: that is to say, gas might find a passage where oil could not, and even at times get from lower to upper strata. Whether so-called *gas sands* do not represent something of this kind is worth consideration.

The Caspian Sea.—There is no intention of describing fully the physical geography and geology of the intensely interesting region of the Caspian Sea, but so many phenomena of interest may be seen in operation around its shores, that a description may be of value in assisting the reader to realize some of the conditions that may have had a more or less direct relation to the origin of petroleum. The Caspian is an inland sea, covering an area of from 170,000 to 180,000 square miles (authorities differing between these two amounts), from which there is no outlet, the level of the water being about 84 feet below the level of the Black Sea. The Caspian is in reality the diminutive representative of the immense expanse of ocean which at some time during the Tertiary period was connected with the Black Sea and Mediterranean, and extended over a large area of Europe north-westward of the Black Sea, and a still larger area of Asia to the east and south-east of the Caspian. The Caspian was doubtless cut off from the oceans to the west at the time that the Caucasian range was thrust up, and from the oceans to the south-east during those orographic changes which resulted in the Himalaya Mountains and the highlands of Afghanistan and Persia, so that any information that can be made to fix the time or times of these great physical changes will also approximately fix the period when the Caspian was isolated from the oceans. That connection with the open sea did once exist is proved by the character of the dissolved salts in the water of the Caspian, and by the fish which abound in this sea. Myriads of fish accumulate around the mouths of the rivers running into the Caspian, and thousands of tons are annually caught and forwarded to Russian markets, but many are, probably on account of the brackishness of the water, profoundly modified varieties of ocean fishes, if not actually distinct species indigenous to the Caspian. They are of a particularly greasy nature. The well-known caviar, for which the Caspian is famous, is simply the roe of the sturgeon, and this oily nature characterizes many of the fish. Whether it has any bearing on the origin of oil one is not yet prepared to say, but it is a fact worthy of note.

The amount of water which flows into the Caspian Sea cannot be less than 30,000,000 cubic feet per minute on an average, for measurements have shown that the Volga alone, which drains nearly half a million square miles of land, discharges sometimes as much as one and a half million cubic feet of water per second, and besides this there are the Ural, Terek, Kura, and Arax, and many others. If this estimation of the water flowing into the Caspian is correct, the annual evaporation must equal this amount—that is to say, 3 feet of water annually, or an average of nearly one-tenth of an inch per day must be evaporated to keep the Caspian Sea at its present level. The amount of salt in the deep southern part of the Caspian—for the northern third of the Caspian is not more than 50 feet deep—is 2 per cent. only, whereas the oceans exhibit 3·5 per cent.



The London Geographical Institute

Map to accompany Thompson's Oil Fields of Russia. To face page 64.

of salt. This peculiarity revives a special interest to discover how a sea, once in communication with the oceans, and in which the evaporation is equal to the supply of water, can not only have failed to increase in density, but actually decreased in salinity from 3·5 to 2 per cent. since it was cut off from the sea.

On the eastern shore of the Caspian is a large basin, named Karaboghaz, separated from the open sea only by a mere strip of land, and whose only communication with the open sea is by a narrow channel about 150 yards wide and 5 feet deep, through which a continuous but fluctuating stream of water, averaging 3 miles per hour, flows, the current being entirely due to the intense evaporation set up in a confined shallow area. The total area of Karaboghaz is about 8000 square miles, and Von Baer, who has specially studied the Caspian, estimates that no less than 350,000 tons of salt are daily abstracted from the sea by this basin alone. As there are many other similar basins of smaller dimensions on the eastern and southern shores of the Caspian, and on the northern shores enormous lagoons where salt is deposited in a manner very like at Karaboghaz, a reason is found for the brackishness of the Caspian,* and an explanation is forthcoming for the intense salinity of some of the strata fringing the coasts.

Into this huge basin are swept daily thousands of fish, which cannot survive the intense salinity of the water, and whose remains must be deposited together with other sedimentary matter. The Russian Government has under its consideration a scheme for closing the channel to this basin in order to save the fish. Violent sandstorms periodically sweep the region of Karaboghaz, and one is led to inquire whether the deposition of huge quantities of known oily fish remain in a deposit of salt, and probably sulphate of lime, where practically the only siliceous matter is sand conveyed by winds, is not forming the material for a future oil field, not unlike, in some respects, the existing oil fields.

Sandstorms.—Sandstorms are very prevalent on the hot eastern and south-western shores of the Caspian Sea during the summer months, when rain rarely falls, and it is an interesting fact that the River Oxus, which within historical times drained into the Caspian, now flows into the sea of Aral; its course has apparently been diverted by sand dunes, *i.e.*, accumulations of blown sands.

After one has passed through the experience of a violent duststorm in Baku, there is less difficulty in realizing how large masses of blown sand may accumulate in sheltered spots, or how considerable deposits may occur in the adjacent sea. After weeks or months of hot weather, without a single shower of rain, the whole of the district fringing the south-eastern shores of the Caspian is covered with an impalpable siliceous earth, actually fine sand. At intervals during the summer a tempestuous wind springs up with a suddenness that can only be imagined by those persons who have witnessed a tropical tornado, and in the course of a few moments the district is enveloped in a dark yellow mist. So thick is the dust or sand that the sun's rays cannot penetrate it, and at times it is impossible to see across the road. Carts are often completely overturned by this dry form of tornado, and the streets are in a few moments cleared of every one whose business does not render it absolutely necessary to go out. Life out-of-doors is almost unbearable; the eyes, nose, and ears become filled with grit as the blinding, stinging sand is driven into the face at a terrific velocity, and the grit can be tasted and be felt grinding the teeth at every motion of the mouth. The exertion of walking in such a hot wind causes moisture to freely exude from the skin, and on this the sand settles and forms a hard crust, so that great discomfort is experienced in moving the facial muscles. Not only do human beings suffer from the effects of these sometimes terrific but always prevalent summer duststorms, but horses and all other animals may be seen shrinking in fear in some sheltered situation. In one very violent duststorm, in which the author and two friends were caught, the greatest difficulty was found in getting the horses they were riding to face it.

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* The salinity of the Caspian Sea differs greatly in different parts and at different seasons of the year. In the shallow northern portion of the Caspian, where the depth of the sea nowhere exceeds 50 feet, the water may be drunk during the winter months, when the ice and snow are melting, whilst in the middle and southern Caspian regions there is always 2 per cent. of salt, except near the mouths of large rivers like the Kura, the Arax, and the Terek.

There is no complete escape from these sandstorms. The fine dust penetrates everywhere; it accumulates in the pockets; it finds an entrance into the watch case, and causes the works to get clogged; it defies double windows and shutters, and the siliceous particles accumulate in the house to such an extent that shovelfuls of sand may be removed from a Baku drawing-room after a storm. The author has seen the sand, during such storms, lie from 4 to 5 feet deep on the Romany-Saboontchy road, causing traffic to be suspended until the mass of blown sand had been cleared away.

Miles out at sea the fine sand in the atmosphere causes a yellow mist, and the dust settles on the decks of the steamers trading on the Caspian.

Dust Diseases.—It has long been suspected that much of the ill health which prevails in the summer months at Buka is due to the prevalence of duststorms. Sometimes as many as 20 to 25 per cent. of the workmen on an oil property are suffering from dysentery and acute diarrhœa, and the mortality amongst children is fearful.

A lurid light has been thrown upon dust diseases by some recent reports on the mortality in South African mines.* From these reports it appears that the death rate among the natives employed at the mines on the Rand is 42 per 1000, although the men engaged are in the prime of life. It is conclusively shown that the death rate is the result of a dust disease, which has been named *silicosis.* Men inhale sharp, angular particles of quartz, and these cause such an irritation of the lung tissues that they gradually become incapable of performing the respiratory functions, and after six or seven years the man dies. Men working rock drills are the greatest sufferers, especially where the holes are drilled upwards without water.

It is, therefore, very probable that irritation of the intestines of human beings, set up by particles of siliceous matter necessarily swallowed, may be largely responsible for the illnesses that prevail in the summer, in which case respirators rather than medicines are required.

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* Return of the Statistics of Mortality, Sickness, and Desertion amongst the Natives employed in the Rand mines during the period October, 1902—March, 1903 (London, 1893).

Report of the Miners' Phthisis Commission, 1902-3, with minutes of proceedings and minutes of evidence (Pretoria, 1903).

Special Features of the Sands, dispersed amidst the Oil-bearing Strata, and their Relation to the Sandstones.—Gas sands, oil sands, water sands, and sandstones have been briefly described in Chapter II., but a more minute account will now be given. The ambiguity of the above designations has been mentioned, and the exact relationship between the various types of sand and sandstones will now be considered.

The very coarse "water" sand, which is so readily recognized by the sharp angular edges and the large size of the particles, approaches very closely in appearance ordinary seashore sand, such as can be collected from any sea beach. The medium quality sands, and from thence in all stages of fineness down to those composed of infinitesimal particles, arouse the greatest interest on account of their direct association with petroleum. All these latter sands exhibit undoubted traces of their æolian origin, and so valuable is the information afforded by this character that the quality of a stratum, penetrated by a drill during boring, can very accurately be foretold by the peculiarities the sands display. An engineer who has for years been constantly associated with the Baku oil fields will estimate the worth of a sand by simply rubbing a little between his finger and thumb, or by placing some on the tongue and observing the sensation against the roof of his mouth when moving the tongue. Only long experience and daily contact with the oil fields will develop this faculty, but even then it is only persons with a keen perception who are able to distinguish correctly.

The coarsest æolian sands are the largest oil yielders, and it is from this class that all the huge spouters have been obtained from the Balakhany, Saboontchy, Romany, and Bibi-Eibat oil fields, and generally the assumption is correct that as the æolian sands increase in fineness the quantity of oil they contain diminishes, until in the finest types gas alone is usually disseminated.

To enable a young engineer to understand the peculiarities of an æolian sand from a microscopic examination, Fig. 10 has been prepared, where various classes of sand have been photographed with a magnification of twenty diameters.

Example 1 shows a good typical specimen of an æolian sand, washed from a shell-bed in the Khordalan district, of which mention is made elsewhere.

Example 2 shows a typical seashore, water-formed sand.

Examples 3 and 4 show a Baku ideal oil sand of æolian origin.

Example 5 shows one of the very fine oil-producing æolian sands.

Example 6 shows a typical Baku gas sand of æolian origin.

No. 1 shows all the characteristics of an æolian sand, and No. 2 all the striking features of a water-formed sand. In the former a large proportion of the particles more nearly represent minute pebbles than fragments of quartz, and they have not only been beautifully rounded, but they have been polished also. In the latter the particles, although roughly rounded, still retain angular edges, and very few of the siliceous fragments have undergone a polishing.

Nos. 3 and 4 illustrate a rich Bibi-Eibat fountain oil sand, and it is a typical representation of all rich oil-bearing sands in the Apsheron oil fields. The particular sample figured was taken from a Bibi-Eibat flowing well, which had only just previously yielded as much as 700,000 poods of oil a day, and had given many million poods of oil and many thousand tons of this sand altogether.

Example No. 3, Fig. 10, with a dark ground, gives the best general view of the particles. In No. 4 the background was made light, so as to show up the dark particles better. These two figures exhibit all the characteristics of a rich oil sand, and an inspection of these will show that many of the grains are more or less rounded and polished particles of semi-transparent mineral. The darker fragments, clearly seen in No. 4, are composed of some hard mineral, and they are always prevalent in the richest types of sand; in fact, they impart to the washed sand a variegated appearance, which serves as a guide to the character of a deposit.

Specimen No. 5, Fig. 10, shows one of the fine oil sands so frequently encountered in the Baku oil-bearing series. These sands are composed of such minute particles of siliceous matter that they are not easily distinguishable from clays when intimately mixed with petroleum, and to the touch they feel like fuller's earth or French chalk. These sands do not, as a rule, furnish abundant supplies of petroleum, and not often fountains, but a good bailing production is sometimes obtained.

No. 6 is a sample of a gas sand magnified to the same degree as the others, and it will be seen that many of the grains are exceedingly fine. These minute-grained sands are generally darkly discoloured, and have a strong petroleum odour; but they do not often yield any oil, although occasionally small productions are secured. In these fine sands, which are in reality the finest dust—dust which would fall but very slowly in air—it is not easy to conceive of any other origin than an æolian, especially considering how free they are from clay. Only the larger fragments are rounded, and the majority of the grains are minute needle-like splinters or crystals of quartz, probably detached from large masses of granites by the expansion and contraction due to rapid differences of temperature. Oil sands contain these minute, sharp, angular fragments (see Nos. 3 and 4, Fig. 10), but naturally the larger particles tend to mask them. The presence of both in the coarser sand is consistent with the æolian origin of the two kinds, and is an important point in connection with the theory of the origin of oil advocated.

If several pieces of sandstone from Baku oil wells are carefully examined side by side, it will be found that they exhibit considerable differences in texture, weight, and composition, but all will be found to be highly impregnated with calcareous matter; indeed, at times, it is really difficult to decide offhand whether to call the rock a *calcareous sandstone* or an *arenaceous limestone*. The cementing material which has caused the formation of the rock is proved to be calcareous by treating a sample of stone with dilute hydrochloric acid, when the calcareous matter is violently attacked by the acid, and silicious and other insoluble particles are left as a powder. Much of the sandstone is accompanied by sulphide of iron, in the form of the hard, glistening pyrites, and where such is the case, the sandstone is not so readily attacked by acid. If the residues left, after treatment of the stone with acid, are dried and examined, they will be found to be identical, in most particulars, with various qualities of loose sand that can be collected in the same regions. The sandstones which accompany the oil strata are consequently surmised to be simply solidified forms of the loose sands, and the problem of interest—which is carefully treated in a subsequent paragraph—is to ascertain

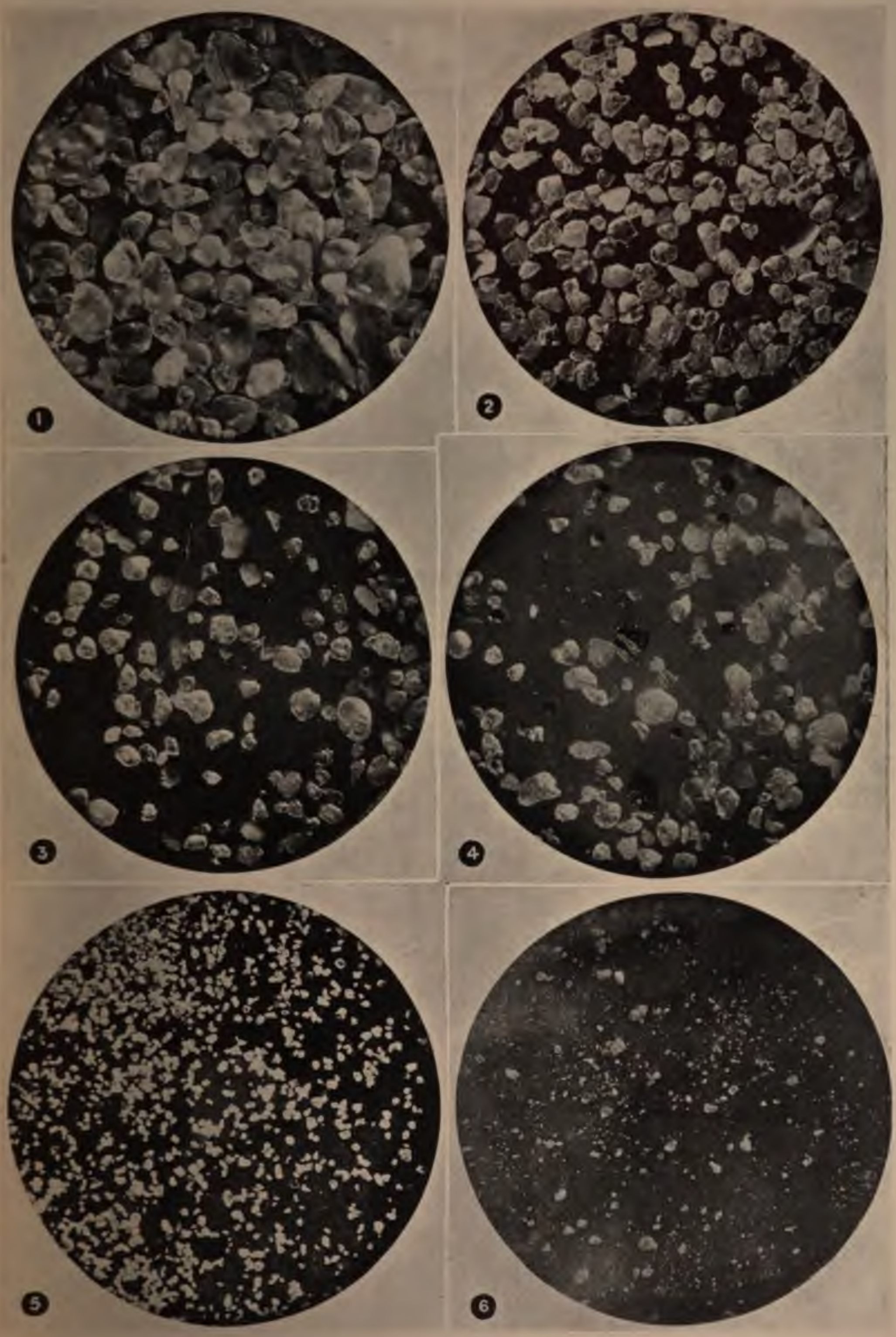

Fig. 10.—Types of Sands.

(1) Typical specimen of an æolian sand.
(2) Typical seashore, water-formed sand.
(3, 4) Baku oil sand of the richest type.
(5) Fine Baku oil sand.
(6) Baku gas sand.

(Each specimen enlarged 20 diameters.)

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the reason for the two forms in close proximity to one another, as all explanations so far attempted do not give any satisfactory reason.

A characteristic sample of calcareous sandstone removed from a Saboontchy well was specially analyzed for this work, and showed the following percentage of composition. It is interesting to observe the small amount of sulphates present in the rock, and a reference to the analyses of well waters on p. 93 also shows almost entire absence of sulphates.

Analysis of Sample of Baku Calcareous Sandstone.

Sodium chloride	0·247
Sodium sulphate	0·580
Sodium carbonate	1·436
Calcium phosphate	0·306
Calcium carbonate	30·627
Magnesium carbonate	1·510
Iron (sulphide ?)	2·542
Sand (with some iron pyrites)	63·164
	100·412

The sand appeared to contain about 7·73 per cent. of iron pyrites; for on ignition it gave off a strong odour of sulphurous acid gas, and lost 2·06 per cent. in weight.

Nodules in Baku Oil Sands.—The occurrence of huge quantities of rounded nodules, which have already been mentioned in Chapter II., is one of the most curious features connected with the Baku oil beds. These nodules consist of more or less rounded masses of calcareous sandstone, similar in all respects to the rock which is described in the preceding paragraph, and apparently consist of fragments of this in some cases. Those which have been collected by the author —the size of specimens being naturally dependent upon the diameter of the wells—vary from 3 to 10 inches in diameter across the largest part, and take all sorts of rounded shapes. The nodules tend to collect near the shoe of the lining tubes of wells, and in some districts seriously diminish the output by interfering with the free admission of oil, unless periodically broken up and removed.

The peculiar roundness, and in some instances almost true spherical shape, of the nodules is no doubt partly due to the violent commotion amongst them and the sand at the bottom of wells during the evolution of gas. That a mechanical origin is not an adequate explanation for the general rounded nature of the nodules, is shown by the fact that where new wells have been bored in the vicinity of old ones, exhausted oil sands, passed through during the work, have been found to abound in nodules, these having apparently been carried towards the points of abstraction in the rush of oil and sand towards the earlier wells. From some wells where there was a strong gas pressure, buckets full of little spherical nodules, about the size of peas, have been collected, which undoubtedly have been mechanically formed from particles of rock in the borehole. For a long time the author was very much inclined to attribute the origin of all the Baku nodules to motion in the strata or at the bottom of the well, notwithstanding the fact that they have been found nearly 1000 feet from the nearest wells which formerly produced. The author, too, has one very fine example of a wooden, mechanically formed nodule, removed from a Baku gaseous oil well, which exactly corresponds in shape with some of the rocky ones. A piece of hard wood had in some way been dropped into the well, and one day the bailer valve was found jammed open with a beautifully made wooden nodule, resembling absolutely in shape many rocky nodules in the possession of the author. The wood had primarily been a flat piece, but the constant movement in the well amidst much sand had worn and rubbed it into a spheroid. The mechanical origin of some nodules is rendered highly probable by the appearance of unequally worn laminæ in them, but whether their formation was of recent occurrence, or contemporaneous with the original deposition of the strata, present evidence is insufficient to prove conclusively, but a probable explanation is offered later. Recent mechanical origin cannot be the whole truth, however, for nodules have more than once been found inside other nodular fragments, a state that was only exposed by splitting open rocky pieces removed from wells. Both Messrs. Nobel Bros. and the author have a specimen of this curious feature, which proves that phenomena capable of producing nodules were in operation at the time of the deposition of the oil strata. The embedded pebble (as it might be termed) in the two particular specimens described, is of a distinctly different texture and colour from the rock in which it is encased.

A certain proportion of the nodules disclose, when broken, a carbonaceous nucleus, like that shown in Fig. 11, and at first sight it might be thought that the preservation of the wood, the formation of a calcareous covering, and the nodular form of the rock, were concomitant phenomena, but this is untenable when it is shown that the nodules containing the wood are not impervious to liquids, and many rounded lumps containing wood are obviously not concretionary. When nodules are split open, the outer portions only show signs of petroleum, but in reality oil is secreted throughout the stone. A lump of stone containing a piece of wood, nearly as large as the one figured, had no odour, and appeared to be free from petroleum, but on exposure to a damp atmosphere it became covered with hundreds of little globules of oil, or so it appeared (the wood even more so than the stone), which globules disappeared after a time. An explanation is probably to be found in the fact that the stone contained much sodium chloride, which deliquesced in the moist air, forming little globules of water, and each of these became covered with a pellicle of oil abstracted from the stone; in fact, the whole stone was porous.

Many of the nodules exhibit a perfectly even and close texture when fractured, and so might be concretionary in nature; the author has not, however, any specimens where a decided concretionary structure is visible.

Some of the nodules have little lenticular patches of clay in them, or, at least, some material which easily washes away in water and leaves a cavity of like shape, whilst occasionally smaller lumps of calcareous sandstone of a distinctly different colour and mechanical texture are discovered embedded in the rock.

Oil Dirt (*Graz*).—All persons associated with Baku oil properties are familiar with a peculiar, thick, oily solution which occasionally appears in wells, and for days, or even weeks, renders the oil valueless. This oil dirt, as it is usually termed, will suddenly appear in the largest producing wells—wells which, up to its appearance and after its disappearance, yield as much as 6000 to 15,000 poods of clean oil a day—during which time the whole of the output has to be thrown away at the rate of 20,000 to 30,000 poods daily. The oil dirt varies in appearance; in reality there are two distinct types. One is composed chiefly of oil filled with curds, resembling soap curds which form on hard waters when washing; the other consisting of a dark yellowish viscid fluid highly charged with water and sand.

The first class of oil dirt is so peculiar in appearance that the author was at one time inclined to attribute to it some connection with the origin of oil. Glasses of these curds have been left standing for months under observation in open and closed glass jars, but the curds show no sign of diminishing, and they neither settle in the oil, throughout which they are disseminated, nor show any inclination to rise. On applying heat to a little placed in a porcelain crucible, the curds and oil are evaporated, and a small deposit of fine sand only is left. In this class of dirt, water does not usually separate, and if it is present it remains in suspension, or in combination with the curds. The thickening may be due to a larger proportion than usual of aluminium oleate, but investigations have not yet been completed to prove such a supposition.

In the second class of oil dirt, water is always present in larger quantities, and the fluid is much more highly charged with siliceous matter; indeed, it seems most likely that an emulsion has been formed by the action of strong gas on a properly proportioned mixture of oil and water, very much like that produced in the air lift (described p. 247). It is possible that the presence of much sand of the finest description, kept in continual and violent motion with the oil and water, may produce an emulsion very like the air churning in the air-lift plant does. A mechanical origin of this latter type of mud is further supported by experiments conducted in the laboratory with oils and sands, where permanent pasty masses have been mechanically produced, similar in many respects to the dirt raised from the oil wells. Further investigations are being conducted in this subject, the results of which must reluctantly be left to a later period.

Sometimes fountains of oil dirt occur, in which case they are a source of endless trouble to the owner, for thousands of tons of this material are ejected, which have to be allowed to run into reservoirs reserved for oil. Two such fountains occurred in 1903, one on Plot 22 C Saboontchy, and one on Plot 140 Romany.

Origin of Petroleum.—Petroleum derives its name from two Latin words, *petra*, "a rock," and *oleum*, "oil;" in German it is known as *erdöl*, "earth-oil;" *steinöl*, or *Bergöl*, "stone or rock oil;" the appellation of the terms arising from the association of the crude material with rocks of various ages. For legal purposes the name is made to cover a variety of inflammable liquids which give off dangerous vapours at various temperatures, but in commerce special names are used to designate purified distillations from the crude petroleum. Petroleum is essentially a mixture of hydrocarbons, *i.e.*, is composed of compounds of hydrogen and carbon; but it generally contains small, but widely divergent amounts of oxygen, nitrogen, and sulphur, which substances are regarded as impurities. Crude petroleum is a somewhat volatile, inflammable, odorous substance disseminated throughout various strata of sufficient porosity to absorb and store it, but such permeated beds are generally overlaid by an impervious formation, which retains the gaseous products in a highly compressed state until relief is afforded by boring into or otherwise tapping the strata. The quantity of petroleum stored in various beds differs enormously, as also does the pressure which usually accompanies it. In some cases loose sands are permeated to an extent estimated to reach from 40 to 50 per cent. by bulk of the stratum, whilst in other cases only a fraction of one per cent. is yielded by the rock, and this only by the aid of blasting. The average in the Baku district has been estimated at 20 per cent. by bulk, and this fairly well agrees with the conclusions arrived at in the previous chapter.

Numerous theories have been advanced to explain the origin of petroleum and its mode of occurrence, but not one, as yet, has sufficiently met all the difficulties of the problem to warrant general acceptance for any oil field. Each oil field possesses characteristics of its own, and the oils themselves differ considerably; therefore it is not unreasonable to suppose that more than one theory may be needed for explaining the origin of oil. Some authorities who have expressed their views on the subject are eminent chemists, whose opinions should carry great weight, and the experiments by which their theories are supported must be taken as proof that petroleum, or something closely resembling it, could be formed in the manner they describe, supposing the suitable conditions existed in nature.

It is not the purpose of this book to discuss, or even to describe, all the theories formulated to account for the origin of petroleum, but merely to deal with such as admit of the introduction of personal observations, based on five years' study of the Baku regions. For fuller information on the various theories the reader is referred to Dr. Boverton Redwood's work on Petroleum.

There are two classes of theories put forward for explaining the origin of oil, viz., the inorganic and the organic; the former ascribing to petroleum a chemical origin, arising from the action of gases upon mineral substances distributed in the strata; the latter attributing the presence of petroleum to accumulations of animal or vegetable matter which have been converted by various agencies into liquid hydrocarbons.

Inorganic Theories.—Amongst the inorganic theories, that of the illustrious Russian chemist, Mendelieff, is one of the most important, and this theory supposes petroleum to have been formed by the action of water, admitted into the earth's interior at intervals during terrestrial upheavals, upon carbide of iron at an elevated temperature, the gaseous hydrocarbons resulting from the reaction, ascending through fissures in the superincumbent strata, and ultimately condensing to form petroleum or bituminous substances. That inflammable hydrocarbons can be readily formed by the action of water on the carbides of certain metals is indisputed, and the investigations of Moissan, the celebrated French chemist, have confirmed such experiments; indeed, acetylene, produced in this manner, is to-day largely employed as a source of illumination.

At the British Association meetings, in 1891, Mr. Ross propounded a theory that led to some discussion about that time, that traced the origin of petroleum to the action of volcanic gases on limestone, under certain conditions. In this theory, carbonate of lime ($CaCO_3$), sulphurous acid gas (SO_2), sulphuretted hydrogen (SH_2), and water (H_2O) played important parts; and calcium sulphate (gypsum) was as constant a result as carbonate of lime a necessity. Carbonate of lime is nearly always associated with oil-bearing strata, but in the Baku district there is no evidence of gypsum in sufficient abundance to give any support to this theory.

Many inorganic theories explain the presence of petroleum by intricate chemical reactions, involving the action of gaseous compounds upon mineral substances, and the ultimate condensation of the resulting products into petroliferous compounds. The Russian geologist, Sokoleff, thinks that petroleum may have been primarily derived from the direct union of hydrogen and carbon in the early stages of the world's history, before the outer crust had formed, but such a supposition would lead one to expect a far more extensive distribution of petroleum than is actually the case.

Petroleum does, however, occur in such a large number of places on the earth, in rocks varying so much in lithological character, and extending through such a great range of geological time, that its production must be looked upon as a normal phenomenon in nature, and not due to very exceptional circumstances, as many theories for its origin would imply.

Organic Theories.—Organic theories attribute the formation of petroleum to the incomplete decomposition, or partial distillation of organic matter enclosed in, and consequently deposited with inorganic material under water. The theories differ in respect to whether the organic matter was deposited in the stratum in which the petroleum is found, or whether the oil had an adventitious origin; the rock in which it is found being merely a reservoir for its storage. They nearly all, however, agree that the change from organic matter to petroleum was effected slowly, at a moderate temperature, probably under great pressure, and under the retarding influence of some mild antiseptic, such as common salt, which is nearly always associated with petroleum deposits. Organic theories ascribe the origin of petroleum to either vegetable or animal matter, and in some cases to both, but it is quite possible that in some oil fields one class has been the cause, and in other oil fields another.

Various kinds of liquids resembling petroleum in some respects have been prepared by chemists from vegetable matter, and small quantities of bitumen are not uncommonly found amidst the English coal measures, which must almost certainly have been derived from vegetable matter. Comparatively deep water deposits, such as there is reason to believe the Russian oil is dispersed amidst, would not be likely to furnish huge supplies of vegetable remains, and one naturally turns to animals as the most likely source.

Origin of Russian Petroleum.—The arguments about to be submitted in favour of the views expressed as to the origin of oil, are given with due respect to the opinions of others who have made a special study of the subject. They are based upon five years' careful personal investigation of the Baku and other Caucasian regions, and an exchange of views with various gentlemen, who, from long experience and with exceptional opportunities for making observations, are well able to speak authoritatively upon the local peculiarities. The author has also been fortunate enough to have in his father, Mr. Beeby Thompson, F.C.S., F.G.S., a constant and willing adviser upon all chemical and geological matters, and the work conducted in his private laboratory has materially assisted in the preparation of this chapter.

The statements about to be made refer, almost exclusively, to the Apsheron oil fields, but as most of the Caucasian petroleum deposits, doubtless, belong to the same age, the arguments will probably apply to other Russian oil-yielding areas of which no mention is made.

Objections to the Inorganic Theories.—One of the chief objections to the acceptance of theories involving the condensation of gases exuding from the earth's interior is the difficulty of imagining how compressed strata can absorb huge quantities of gaseous products; volumes which astound one when it is realized how small a bulk liquid petroleum must assume compared with the same in a gaseous state. In the case of metallic lodes, the minerals have crystallized on the sides of fissures where the vapours exuded, and in the case of some of the American oil strata an explanation is afforded by the dolomitic action which has taken place, whereby the double carbonate of calcium and magnesium is formed, which occupies less space than the original limestone, and consequently admits of saturation with extraneous fluids. Where water impregnates strata, the formation is either a very regular porous one—one in which the particles are fairly large—or it is overrun by fissures, wherein the water circulates. Russian petroleum neither runs in fissures nor does it impregnate a regular uninterrupted formation. In most districts where phenomena have occurred, resulting in the evolution of gases from below, metamorphic action has taken place, but in the Baku oil deposits there are no indications of metamorphism to be observed anywhere.

An important point which detracts from the value of the volcanic theory is the occurrence of the prolific beds in well-defined zones, the intermediate strata being either quite dry or nearly devoid of petroliferous signs—although in some cases suitable for the reception of oil, and similar in most respects to the oil-bearing beds—or filled with water. In the Balakhany-Saboontchy district a succession of sands, separated only by thin layers of clay at intervals, immediately underlies the well-defined oil-bearing series. Many of these sands are full of water, and quite devoid of petroleum, but, apparently, interspersed in them are oil-producing laminæ, so that it is difficult to understand why the lower sands, favourable in all respects for the storage of fluids in their interstices, should have escaped saturation, if the productive strata were impregnated by means of ascending gases.

The above-mentioned facts are sufficient to direct attention to other causes for the origin of oil in the Baku regions, and subsequent observations will still further support this view. If any inorganic process has been responsible for the production of petroleum in the Russian oil fields, the origin of oil must rather be looked for in chemical actions that have occurred in the strata themselves, without the assistance of extraneous gases, although, perhaps, with the aid of terrestrial forces accompanied by heat and pressure. The Baku oil-producing strata contain sulphide of iron, in the form of the hard yellow pyrites, carbonaceous matter, calcareous material, common salt, and generally water;

and evolutions of sulphuretted hydrogen (SH_2), carbon dioxide (CO_2), and sulphur dioxide (SO_2), besides petroleum gas and steam, prove that chemical actions take place, or have taken place, between compounds in the formation. The difficult problem to solve, if we attribute to petroleum an inorganic origin, is how, under reasonable conditions found in nature, petroleum could have been formed from mineral substances, and this leads one to consider organic theories, which, in the Baku district, afford a much more likely explanation.

Objections to Vegetable Theories.—It has been generally thought, and, indeed, often stated that the oil-bearing strata of Baku are free from organic remains so far as the drill has penetrated, although the limestone beds overlying the oil series abound in the shells of molluscs, being, in fact, almost made up of fossiliferous remains. This idea is quite fallacious, for the author has collected both animal and plant remains from the oil beds, and considering what a comparatively small proportion of material is removed from oil wells, it must be assumed that such fossils are fairly prevalent.

Some clays lying between the oil zones have been found to contain shell remains and numerous hair-like fibres, the latter creating the impression that they are the veins of leaves; indeed, Mr. Anderson, of Messrs. Nobel Bros., has obtained what appears to be a whole leaf impression. The fibres are evidently of vegetable origin, but whether they belong to terrestrial or aquatic plant life, or whether they grew *in situ*, or were swept there by currents, or were primarily carried by winds, present information does not allow one to decide. It is, however, interesting to note that old Baku boring-masters have for years observed these fibres in some of the clays, and used to consider that their presence denoted the existence of an oil source a little deeper. Oil does appear in clays which display an abundance of these carbonaceous fragments, but it is equally common in clays where the fibres are absent, so that no great importance attaches to their presence in this respect.

During boring, the strata are so pulverized by the bit that all traces of fossiliferous remains are destroyed, but during bailing, and when fountains are blowing, numerous fragmentary pieces of compact sand and sandstone are raised or ejected from the wells with the loose sand, and it is from these that so much valuable information is obtained. These pieces of sandstone vary considerably in constitution, but they invariably contain carbonate of lime in varying proportions, but, in addition, many contain a considerable amount of carbonaceous matter. Messrs. Nobel Bros. have some excellent specimens of these remains in their Baku geological collection, where slabs are exposed exhibiting a perfect mass of large fragments of carbonaceous matter. Some of the fragments of sandstone split with ease along the laminæ, when struck with a hammer, and the separated parts often disclose streaks of fragmentary vegetable remains along the cleavage plane. In addition to this, large boulders or nodules are frequently raised from the Baku wells, and these will be found, in many cases, to contain well-preserved stems of wood; but the important point to note is, that so far as the author's experience goes, the wood is preserved as such, and is neither silicified, calcified, nor carbonized to any great extent, and there are no traces of bitumen in or around it. In a previous paragraph it was shown that the preservation of the wood and carbonaceous matter is not due to encasement in a calcareous or other protective covering, but that the stone in which it is enclosed is comparatively porous.

It will be seen from the foregoing remarks, and those in Chapter II., that, so far as the Baku district is concerned, there is no evidence of there having been enormous accumulations of vegetable matter of any kind, such as would be required to account for the immense supplies of petroleum, supposing it had a vegetable origin. The fact that vegetable matter is widely distributed amidst the oil-bearing sands, and that it exists in a fair state of preservation, although there are no special reasons for the preservation of the specimens found, indicates the improbability that other vegetable matter ever existed, and consequently the unlikelihood of petroleum having been derived from vegetable remains. If there had been signs of a transitorial condition in the wood found, or if there had been no signs of vegetable matter whatever left, a plausible vegetable theory might, perhaps, have been formulated by ignoring the general physical conditions which have been or are to be mentioned. Fig. 11 shows a specimen of well-preserved wood, embedded in a Baku calcareous sandstone.

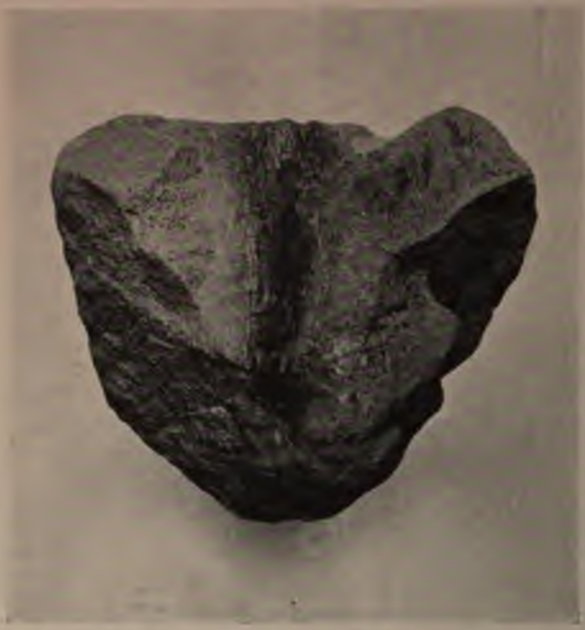

Fig. 11.—Calcareous Sandstone Nodule, with Carbonaceous Nucleus, removed from a Saboontchy Oil Well, 1400 feet deep. $\frac{2}{3}$ natural size.

Before dismissing the subject of the vegetable origin of petroleum, a brief reference should be made to the interesting and important investigations of the German chemists Gustav Krämer and Adolphus Spilker, although they may not have any direct bearing upon the origin of oil in the Baku district, as the organisms required must be assumed to have been present in great abundance, against evidence and probabilities; moreover, distillation was necessary to obtain the results by artificial means.

The above-named chemists, by treating, in various ways, some *diatomaceous earth* from a drained lake in the Uckermark, succeeded in getting products similar to those which go to form petroleum. Under different conditions of pressure and heat, they obtained methane, olefines, carbon dioxide, and semi-liquid paraffins. By distilling the wax of *green algæ* similar products were obtained. Messrs. Krämer and Spilker express the opinion that *ozokerite* is an intermediate stage between the wax of algæ and petroleum, the products of distillation being of the same kind, although they are formed in different proportions.

The previous presence of green algæ in the Old Baku Seas cannot be proved or disproved, although it is probable that the conditions under which the oil strata were deposited was not favourable to their life; of the diatoms (algæ with silicious frustules) abundant evidence must have remained if they had been concerned in the production of petroleum, but very few have been recorded from the Baku district.

The Animal Origin of Russian Petroleum. Having failed to find sufficient reasons for accepting either an inorganic or a vegetable origin for Russian petroleum, the last resource is an animal origin. Of course, there is nothing new in ascribing the origin of petroleum to animal organisms, but it is hoped that the new way of putting the case for an animal origin, to be given later on, may prove to be more definite and complete than others that have preceded it.

Any theory whatever, to be acceptable, must be in conformity with observed facts, so that the facts already dealt with, which bear upon the problem, will first of all be enumerated, and a few others be added as occasion requires.

1. The oil is mostly found in sands or sandstones, but certainly does also occur in some clays.
2. The oil-bearing sands swell out in thickness or diminish, and may become mere laminæ, or cease altogether as recognizable beds, in the most erratic manner, within comparatively short distances.
3. Certain belts or zones in the vertical sequence of beds are generally productive of oil, and serve as a guide; but, singularly, some of the intermediate strata which appear to be quite suitable for the reception of oil, being indeed very similar to the oil-bearing ones, yield none.
4. A "water sand" is found all over the Saboontchy-Romany plateau; it is always full of water, yields no oil, and serves as a datum.
5. "Gas sands," so-called, which it is important to observe are the finest sands, *i.e.*, composed of the smallest particles, are not so erratic in occurrence as the oil sands.
6. The sands, where so named, are nearly free from clay, though, owing to the extreme smallness of the particles in some, whilst more or less saturated with oil they may appear to be clays.
7. Some samples of strata show a rapid succession of laminæ of sand and clay, each layer being, perhaps, not more than $\frac{1}{32}$ inch in thickness.
8. Rather low down in the series, thin oil laminæ may occur amidst a succession of sands and clays containing no oil.
9. Clay beds alone show both continuity and moderate regularity in thickness. They may be from 60 to 80 feet in thickness, but at times are quite thin, as above observed.

10. The clays are grey, blue-grey, or green-grey in colour.

11. Most (if not all) of the clays are more or less sandy, and thin layers of sand may occur in their midst.

12. Every sand and sandstone examined chemically for the purposes of this work yielded carbonate of lime, phosphates, and petroleum, though to obtain evidence of the latter it was sometimes necessary to treat the rock with benzoline or some other solvent. It is not asserted that every sand and sandstone does contain all the above-named substances.

13. The number of clays examined chemically has been small, but those available for the purpose contained carbonate of lime, phosphates, and petroleum, the same as the sands.

Physical Conditions.—The comparative regularity in thickness of the clays, combined with greater continuity independently of thickness, points to the conclusion that clay was the normal deposit from the water of the district under consideration. A distance of 250 miles from land is generally looked upon as the limit of terrigenous deposits, such as the Baku oil series must be considered to be, though the distance named may be greatly exceeded where large muddy rivers flow into the ocean; for instance, the Indus is said to carpet the Arabian Sea with mud for 1000 miles from land. Still, considering the intercalated sandy deposits, prevalence of wood, and probably of leaves, the smaller limit of distance seems the more reasonable.

As to the depth of water—bearing in mind the results of Russian observations in the Black Sea (of which more will be said later)—viz., that sulphuretted hydrogen increases in amount from 200 fathoms downwards, and that below about 200 fathoms carbonates are formed at the expense of sulphates; also the direct observations in the Baku strata that carbonates are abundant and sulphates rare, both in the rocks and in the waters from them, and that iron pyrites is a very common constituent of the sands, it seems probable that the deposits were laid down in water more than 200 fathoms deep. The colours of the clays or muds point to a similar conclusion.

No doubt fluctuations of depth and of distance from land occurred within the long period embraced by the deposition of the oil-bearing series, as there is no question that great changes did occur only a little later; therefore the so-called "water" sand may have been a water-formed deposit; and this conclusion admirably fits the explanation of the absence of oil in it, and possibly some other beds.

The sands themselves largely indicate their æolian nature; but independently of this, it is scarcely possible to conceive of the intercalation of deposits of sand, most irregular in horizontal distribution, and in the size and character of the sand grains, with tolerably regular clay beds, on the supposition that they were both derived from the same source and distributed in the same manner by water action. By considering the sand to be blown sand, then the coarseness and fineness of the material of different deposits, the rapid thickening and thinning of many of the beds, the thin alternate laminæ of sand and clay, and the more uniform distribution of the finer gas sands, are all easily explained by changes in the velocity, the direction, and the continuity of the wind which lifted and carried the sand to its destination.

Even crediting the wind with the whole of the distribution, it is not essential that all the sand should be of æolian origin, for seashore sand might also be lifted and carried long distances to sea by suitable winds; but then one would expect to find traces of shells of molluscs in such sand, and of these, so far, none has been found. The carrying power of the wind is very great at times, but it is scarcely conceivable that the coarser oil sands could have made a very long aërial journey over water. Hence, assuming that no great earth movements occurred in the interval between successive deposits, comparative nearness to land seems an essential condition, in accordance with previous remarks.

Endless physical possibilities might be requisitioned, if necessary, to explain any peculiarities of a region that, since the deposition of the earliest (deepest) oil strata, has passed through such great changes as are involved in the uplifting of the Caucasian Mountains, the Hindoo Koosh, and Himalayas. Actually, however, the conditions now existing to the south of the Caspian area are very little different from those required for the formation of petroliferous sands, the southern portion of the Caspian Sea being situated to the north and about the middle of the immense, long, hot, rainless, barren, sandy deserts extending from near the western coast of Africa to Mongolia, over which area insolation and deflation have full play. In the earlier part of the Tertiary period, and probably in the period during which the oil strata were being deposited, the Caspian area had its most open communication with the large oceans between India and Arabia, over the present Persia, etc.

Carbonate of Lime.—The ever-present carbonate of lime may perhaps claim a little attention here. That this substance is the only binding material, the only agent by means of which sands have become sandstones in the oil regions of Baku, is evidenced by the fact that when the sandstone is treated with hydrochloric acid only loose sand is left. Now, here comes a difficulty which must be met: since carbonate of lime is everywhere present, even abundant, why are not all the sands sandstones?—a question which leads to the further one, where did the carbonate of lime come from? It could scarcely be derived from the blown sands alone, because the clays are very calcareous, and even pass into marls at Grosny. With the sands an equal difficulty arises, for, supposing the carbonate of lime to have been deposited as calcareous sand with the siliceous matter, it must have been dissolved and re-deposited to form stone; and why, then, only in some parts and not in others?

On the whole, the simplest plan appears to be to assume that, since the calcareous matter is present everywhere, it was contained in the water, partly dissolved, partly as calcareous mud which would be deposited as sediment, partly as marine organisms with calcareous tests or skeletons. Whether this is a true statement or not of the conditions, it meets the difficulties well. That calcareous matter existed in solution in the water, and that marine organisms utilized it, requires no special proof; that sedimentary carbonate of lime also was carried by the water is most probable, since this mineral is so very abundant and yet traces even of calcareous organisms are rare.

The Nodules.—With a fairly constant supply of calcareous matter and clay a calcareous clay would be formed, such as is found; but with a constant supply of calcareous matter and an inconstant supply of sand, layers of variable composition would be formed, some calcareous enough to form stone, others not; but even so, beds of sand and beds of stone, and not nodules, would be formed, and quite certainly some of the nodules have been parts of stratified beds.

It will be virtually proved later that marine animals were very abundant in these deposits, and carbonic acid gas certainly one of the products of their slow decomposition. A layer of recently formed calcareous sandstone might or might not be sufficiently impervious to gases and liquids to actually prevent their passage through it, but would offer some impediment to the flow of the gas, so that a much higher pressure would be needed to force a passage through it than through sand, and a stronger solution of carbonic acid would necessarily result, and one having greater solvent power for carbonate of lime. The most readily permeable parts of the stone would gradually monopolize the discharge of carbon dioxide and other gases from their immediate neighbourhood, with the result that they would be more attacked and dissolved, and other parts less so. The vents so opened would be enlarged, and the edges of the stone more and more rounded (weathered, as we should say, if atmospheric carbonic acid attacked such a stone), and so the beds become discrete fragments, or nodules, to be attacked on all sides, but yielding most easily at their ruptured edges.

Again, the gases might find vent into the water above, or into a higher layer of sand not then so highly charged with gas, a mere equalization of pressure resulting. In the latter case, indeed in either case, the saturated solution of carbonate of lime which necessarily results from the presence of abundance of carbonic acid gas under pressure in water in contact with carbonate of lime, would readily part with a portion of it in a crystalline form, and so concretionary nodules possibly be formed. A small separated piece of the calcareous sandstone, or even a piece of clay, or wood, might be the starting-point of a fine crystallization which ultimately extended and covered it, and maybe other things, a concretionary nodule being the result, and possibly a nodule within a nodule, such as has been found.

According to this explanation, the abundant ordinary nodules are of contemporaneous manufacture, and without such an explanation their contemporaneous origin must have been assumed.

Clay beds were not often broken through in the manner described above, though there is evidence that some were, because of their uniform impermeability; their increasing thickness enabled them to withstand the increasing gas pressure below.

Marine Calcareous Organisms.—Some of the clays of the oil series do contain fossils, therefore presumably some of the sands did. For reasons given above, calcareous remains of fragile shells had a decidedly bad chance of being preserved, excepting in a stone; but since *none* has been discovered in stones, we may presume they were scarce, as they would be likely to be according to our diagnosis of the physical conditions prevailing during the deposition of the oil series. Fortunately, some foraminifera have rewarded the painstaking search for them in a number of sands; they are certainly not common, but both the Romany and Saboontchy districts have yielded them from both oil sands and gas sands. At places large numbers occurred together, and this fact makes it all the more probable that the absence of evidence of shells of molluscs in the sands is due more to actual absence of the shells themselves from the deposits, than to after comminution or dissolution.

Fig. 12 shows a number of specimens of foraminifera collected from oil and gas sands in the Saboontchy and Romany districts. These were kindly inspected and named, so far as their condition allowed, by the Rev. J. F. Blake, M.A., F.G.S.

Marine Siliceous Organisms.—One compact, hard, nearly white stone, containing a rounded piece of quite ordinary calcareous sandstone, looked peculiar and interesting. On putting some of the white stone only into rather strong nitric acid, a trifling effervescence was observed, and the stone seemed almost unattacked by the acid. After twelve hours, however, the liquid was found to be a thick jelly, which would only just pour out of the vessel, apparently silicic acid. The stone is still under investigation, hence nothing can be said definitely; but from its occurrence amidst deposits, no others of which show characters anything like it, there is more probability that it consists of the finely divided siliceous remains of organisms such as *diatoms, radiolarians*, or *sponges*, than that it is a siliceous mineral.

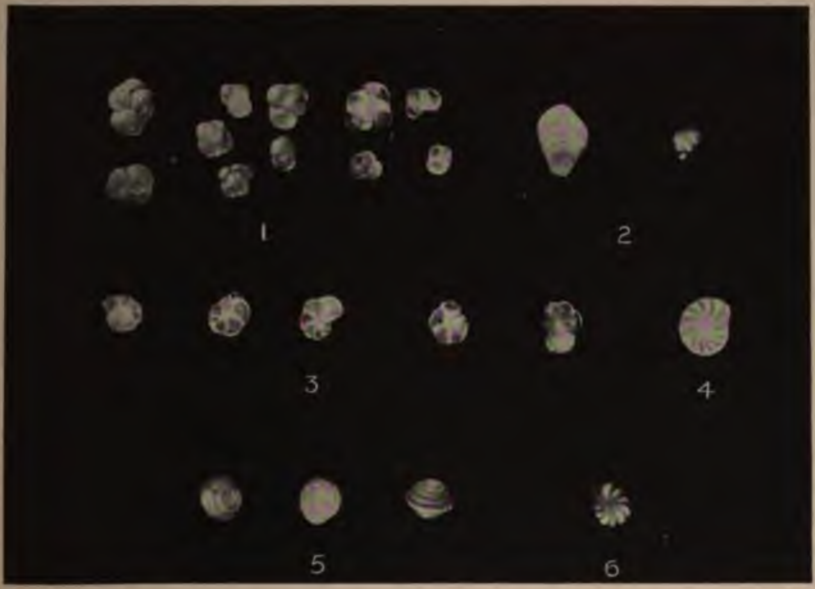

Fig. 12.—Foraminifera taken from Saboontchy Oil and Gas Sands.
(Magnified 25 diameters.)

(1) Globigerina. (3) Discorbina. (5) Trochammena.
(2) Textularia. (4) Polystomella. (6) Polystomella.

In addition to those figured, specimens of Cristellaria, Nonionina, Lageria, and Nodosaria were discovered.

Phosphates.—Every deposit from the oil series of Baku, whether sandstone, sand, or oil-bearing clay, that has so far been specially tested, has yielded phosphates. The phosphates are insoluble in water, indeed, could not be otherwise in presence of so much calcareous matter, and are not found in the oil. They are best extracted with nitric acid, and have sometimes not been detected after treatment with hydrochloric acid, although afterwards found to be present in the material. Calcium phosphate is insoluble in water only, but is soluble to a limited extent in water containing common salt, and from such dissolved phosphates marine organisms must chiefly obtain their supply. With this proviso it may be said that phosphates cannot exist in solution with carbonate of lime; they might certainly have constituted a part of the sedimentary calcareous matter which has been postulated (p. 81), but since the quantity of phosphates (calcium phosphate with some iron phosphate) appears to be commensurable with the oil, a direct connection between the two is an inevitable induction; in other words, whatever action or organism yielded the oil yielded the phosphate. This universal distribution of an abundance of phosphates in the oil-bearing series has never before been pointed out, but clearly it has a most important bearing upon a theory of the origin of the oil.

Speaking with the limited knowledge which attaches to a quite recent discovery, it is put forth as a proposition, that the indigenous or adventitious origin of the oil in any bed can be decided by the presence or absence of phosphates in the same, or by the amount of such relatively to the oil obtained. Applying this to the shell bed yielding oil (see p. 89), phosphates are present, but the amount is not commensurate with the oil present—that is to say, the oil is large, the phosphates small; the inference drawn is, that the oil has an adventitious origin. The bed is a dead shell bank, a beach formation probably, and so is not likely to have produced oil. The shells themselves would yield the phosphates found.

The Petroleum-forming Organism.—The general occurrence of petroleum in all kinds of deposits in the oil series, with most doubtful entire absence in any, originally, points to a continuous supply of the petroleum-forming organism. The absence of oil in some beds amidst others yielding, or *vice versâ*, could be explained by varied physical conditions in the oil series themselves; for instance, a thin bed of sand yielding no oil may be only the attenuated periphery of a thicker and even rich oil bed. Still, the great uncertainty about finding oil leads one to think that the supply of the petroleum-forming organism was very variable in quantity, or in other words, that the richest oil beds indicate a mortality much beyond the ordinary, as the result of an epidemic, or a catastrophe of another kind. What this was it will be our business to consider almost immediately.

The notes on the Caspian Sea and on sandstorms (pp. 64, 65) were inserted with intent. Bearing in mind the abundance of fish in the present Caspian Sea, it is impossible to avoid the conclusion that fish were at least common in the Oligocene and Miocene seas; that they must have died and been buried in the sands and clays is equally certain, yet no direct physical trace of one has yet been discovered,* or at least no record exists of such a discovery as far as the author is aware. If fish did exist, then they have been wholly transformed into other substances, which substances should be found now. Supposing petroleum, petroleum gases, and phosphates constitute such relics, then fish must have been enormously abundant;[*] and in the present condition of the Caspian area we have a clue to the cause of the extreme abundance of dead and decomposed ones in the oil-bearing district about Baku.

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* Little black fragments have been occasionally found by the author, which closely resembled pieces of teeth, but nothing of a decided character has ever been found by him.

Imagine a long sandstorm or succession of sandstorms to deposit fine acicular crystals of quartz over a particular area of sea until the water was as thick with them as the atmosphere sometimes is now, would the fish, which cannot escape from, which cannot in any way evade the crystal shower, be better able to survive it than the Rand miners, who only live in the dust a portion of the day? They would succumb in large numbers as surely as the natives of West Africa do to the insidious powdered glass of the Fetish-men poisoners.

An equally important point is, that the high mortality would not be accompanied by any contagious or infectious disease which could spread to neighbouring regions by the fish themselves, or contaminate the water for others coming in. The animals, fish and other organisms, would be killed; they would die from an accident—from silicosis, in fact. The fecundity of the survivors would probably not be impaired, nor the vitality of the species or genus be reduced in the slightest, but rather improved by killing off the weaklings.

The water would be considerably improved in some respects by the sandstorms even, for much sand passing through water would have somewhat the same effect as water passing through much sand—a point possibly of much importance in another connection.

The Formation of Petroleum from Animals.—According to Dr. Boverton Redwood,[†] Höfer and Engler are the most noted exponents of the animal origin of petroleum, but it must be noted that neither of these chemists has been able to obtain or to point to experiments where anything resembling petroleum has been obtained direct from animal matter. Engler concludes that petroleum was formed from the fat alone of animal matter, by the combined action of pressure and heat, or by pressure alone. Zaloziecki has a similar idea. He apparently believes that the nitrogenous matter of the animal organisms was first of all disposed of, and that adipocere, which comprises the fatty matter of the remains, was covered with sediment, and then gradually converted into fatty acids, which finally decomposed into hydrocarbons; adipocere, ozokerite, and liquid petroleum being produced in the order named.

Most supporters of the theory of an animal origin for petroleum tacitly admit or openly declare that a special process of decomposition is needed to produce the results observed, and that some retarding influence must have been at work for the production of such incomplete decomposition products as the hydrocarbons. Common salt is usually invoked as an antiseptic to retard decomposition, as well as a poison to account for the abundance of organic remains. The manner of accounting for an abundance of organic remains which has already been given, it will be found, differs entirely from any others previously put forward. The method of accounting for the production of gaseous and liquid hydrocarbons also is essentially new, though it agrees very well with the opinion of Zaloziecki quoted above.

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[*] It is not intended to exclude other animal organisms when speaking of fish, because it is highly probable that other marine animals were also abundant, of which no physical traces remain.

[†] "Handbook of Petroleum."

Vegetables, under the vitalizing influence of light, build up more or less complicated organic structures out of much simpler organic and inorganic substances, by a process known as anabolism; but these substances—cellulose, starch, etc.—are more stable than the organic substances constituting animals, and may exist without great alteration for long periods under ordinary conditions. If wood is subjected to the severest strain on its constitution, viz., moist, ærobic bacterial action, complete decomposition will be a very slow process, but the products will be simple organic and inorganic substances, almost identical with those out of which it was formed, such as carbon dioxide, water, ammonia (passing into nitrites and nitrates), and inorganic salts (ash).

In a marsh or stagnant pond with a thick deposit of decaying vegetation, where there is a deficiency of free oxygen and ærobic bacteria in the water, and probably an abundance of anærobic bacteria, then together with carbon dioxide unoxidized products of decomposition are evolved, such as the hydrocarbon methane (marsh gas), and possibly sulphuretted hydrogen, phosphuretted hydrogen, and free nitrogen and hydrogen; the denitrifying organisms breaking down the normal product, ammonia, into nitrogen and hydrogen, whereas ærobic bacteria would tend to build it up into nitrates. The essential points in this section dealing with vegetable matter are, however, that wood could exist where animals would be totally destroyed as such, and that hydrocarbons and other unoxidized products are given off where there is a deficiency of free oxygen, even from vegetable matter.

Animals, directly or indirectly, live on vegetables, but whether they eat vegetables or other animals, the first action of digestion is to break down the food into more soluble substances, which in turn are reconverted into less soluble substances as a part of the animal. These new substances may be neither more nor less complicated in structure than the original food—they may be identical in fact. The process of change from one to the other is known as metabolism.

The life functions in an animal being more numerous and more complicated than in a plant, the substances taking part in them are less stable; hence decomposition into simpler compounds is more easy on withdrawal of the vital force. Not only will saprophytic bacteria more quickly and effectually break them down, but in all probability the highly complicated, unstable compounds would naturally revert to simpler ones without bacterial aid, by a purely chemical process, to which the name katabolism may appropriately be applied. In the absence of extraneously available oxygen, with probably the assistance of anærobic bacteria in the early stages, hydrocarbons would certainly be formed, and marsh gas is likely to be the earliest gaseous one.

Applying all this to the Baku oil deposits, and taking our view of the conditions from observations made in the Black Sea by Russian and other investigators; down to a depth of 100 fathoms or more, the sea contains free oxygen, ærobic bacteria, and abundance of animal life. A sandstorm occurs, and fine acicular crystals of quartz, with coarser granules, are spread over the waters. The sand sinks, and in doing so carries down with it a large proportion of the ærobic bacteria and other small organisms (a process well recognized in the purification of waters); it also so injures the respiratory organs and impairs the respiratory and other functions of fish, that they die in large numbers, and drop into the deeper water, 200 fathoms or more below, within which anærobic and only anærobic bacteria can exist. No such clarifying action as that spoken of above would occur in the deeper water, partly because the larger (heavier) particles would sink more rapidly than the smaller (lighter), and so bring about a vertical separation, and partly because a surface (horizontal) distribution gradually becomes a cubical one, even with particles of approximately the same size.

In this deeper water—200 fathoms and downwards—new conditions prevail; certain anærobic bacteria decompose the sulphates, forming carbonates at their expense, and setting free sulphuretted hydrogen. At the bottom, where dead animals accumulate, septic-tank conditions prevail. Sulphuretted hydrogen is formed from the sulphur in the animals, which, combining with the iron present in the sand, forms iron pyrites. Nitrogen rather than ammonia is formed from the nitrogenous organic matter, thus accounting for the small amount of ammonium salts found in the waters. Probably the simplest and earliest-formed hydrocarbons—methane and ethane—are in part produced at this stage by nascent hydrogen, from ammonia, acting on carbon. Much of the oxygen is used up in forming carbon dioxide. The fats being more stable than the other soft tissues of the animals, owing to absence of nitrogen and small proportion of oxygen, are the last to break down; and, even if they do form some carbon dioxide and some water in breaking down, must leave an excess of carbon and hydrogen to form hydrocarbons. Actually, no doubt, most of the oxygen of the fats is used up in forming the fatty acids always found in the oils and water from oil sources. (See Analysis of Waters, p. 93.) Finally, the disintegrated skeletons and other hard parts yield, as a natural result of the other changes, phosphate of lime and carbonate of lime.

Some of the changes indicated above no doubt occurred before the animal matter was completely covered up, but on account of the prevalence of gases under high pressure in the oil beds, we are inevitably led to the conclusion that they mostly took place afterwards, in which case katabolism rather than bacterial action was the more potent influence at work in the formation of petroleum. No special retarding influence is needed, it will be observed, since there was an absence of accelerative conditions.

Incidentally it may be pointed out how nearly the theory above sketched out comes to some of the inorganic theories which have been based upon experimental research in the laboratory. These inorganic theories appeal to powerful deoxidizing agencies, such as iron at a white heat, to remove oxygen from water and carbon dioxide, which liberates carbon and hydrogen in the form of an oily liquid much resembling petroleum. We have virtually removed oxygen by excluding extraneous sources, and by giving the small quantity of combined oxygen so many atomic competitors that most of the carbon and hydrogen has no other recourse than to form hydrocarbons.

The Occurrence of Petroleum Deposits.—It will be seen that, according to the explanations given of the probable origin of petroleum, no very exceptional conditions are needed for its occurrence in any kind of bed in any part of the world. The conditions are: (1) a supply of the petroleum-forming organism, possibly any kind of animal (or plant?); (2) deposition in water deep enough to provide anærobic conditions only; and (3) a rather rapid covering up to prevent loss of the products of decomposition. The rareness of workable deposits of petroleum being due to (*a*) comparative scarcity of the organisms themselves; or (*b*) the absence of such conditions as would lead to a high mortality amongst the organisms; and (*c*) *especially*, the absence of sufficient sediment to rapidly cover up the organisms in water deep enough to provide anærobic conditions. All this brings us back to the peculiar influence of great quantities of blown sand in the Baku region. The water sand, if it is a true water-formed sand, should yield no oil, both because the depth of formation would not be great enough, and the supply of the petroleum-forming organism would not be exceptional. The fossiliferous limestones of the district yield no oil, both because the depth was not sufficient and the deposition not rapid enough, the former, perhaps, being more potent than the latter.

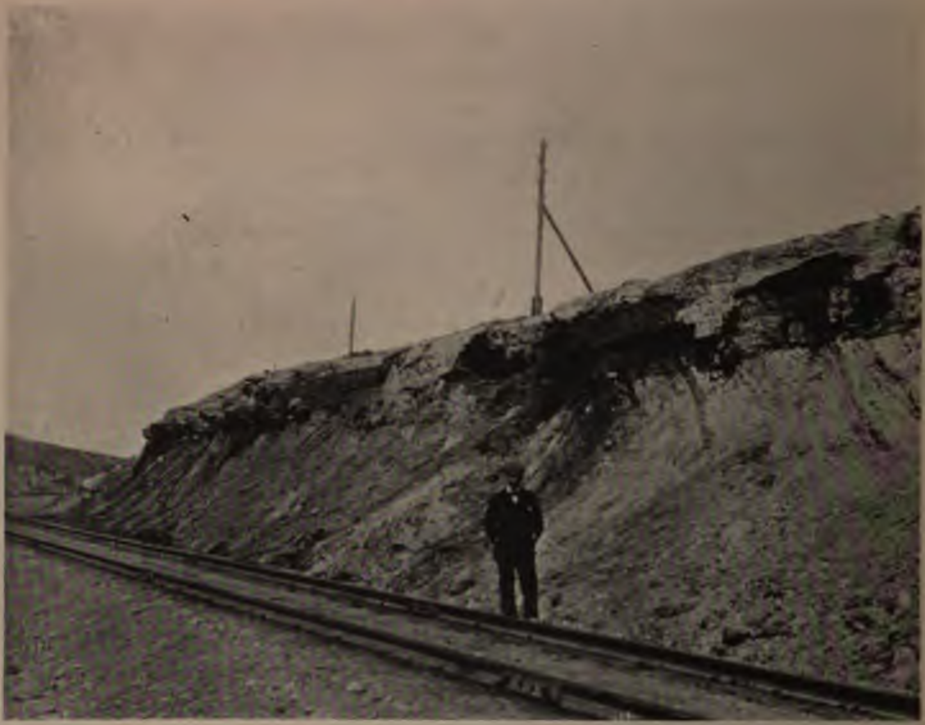

Fig. 13.—Section of Railway Cutting near Khordalan.
(Apsheron Peninsula.)

Interesting Geological Section in Khordalan District.—In the Khordalan district the Vladikavkas Railway passes through a cutting wherein the oil-bearing series is exposed. As this is the only vertical section of the Apsheron oil-bearing beds the author has ever found, he took several photographs, two of which are here reproduced (Figs. 13 and 14). The section is particularly interesting for several reasons. The strata dip at an angle of about 20°, and are overlaid by a horizontal, sedimentary, stratified deposit, at the base of which is an oil-impregnated shell-bed. Petroleum freely exudes from the shell-bed lying unconformably over the main series, and it is collected in tubs at the base of the cutting. Fig. 13 gives a general view of the railway cutting, and Fig. 14 shows a closer view of the strata; but, owing to the reflection of light from the surface of the oil, the oil drainings actually show as silvery white instead of black.

The shell-bed lies immediately above the lower series, but is covered by other sedimentary beds which are not petroliferous in character. The shell-bed is composed almost entirely of shells, chiefly lamellibranchiata, but gasteropods are also present in fair numbers, the latter, curiously, being better preserved than the former. I. and II. (Fig. 15) show pieces of the shell-bed about natural size; III. shows a few fair specimens separately photographed and enlarged to two diameters; and IV. shows a group of shells, also enlarged two diameters, recovered from the bed by washing with benzoline. On treating the cleaned bed with dilute hydrochloric acid, and so removing the calcareous matter, a sand consisting of well-rounded quartz grains (see No. I. Fig. 10), with particles of a dark-coloured substance, was left. The weights of the components of the shell-bed were taken, and showed a composition of—

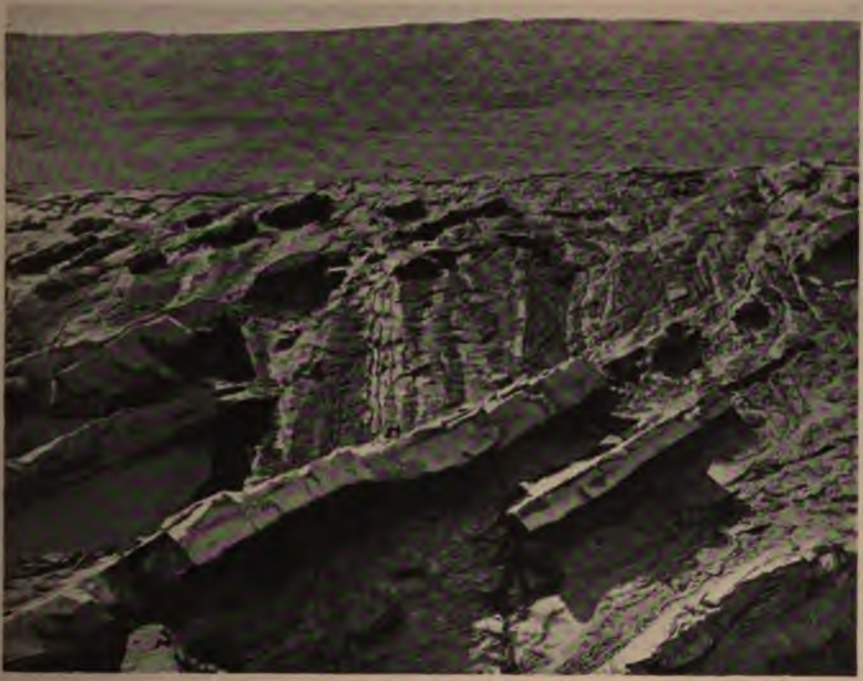

Fig. 14.—Close View of Exposed Section in the Khordalan Railway Cutting.

Shells picked out	3·6 per cent.
Fragments of shells	71·0 ,,
Dark-grey pebbles	1·9 ,,
Sand and fine *débris* of shells	23·4 ,,
	99·9

The shell-bed is quite unlike any of the limestone rocks of the district, and any formation met with elsewhere in the Apsheron, so far as the author is aware.

At first one was led to attribute the presence of the oil to the original occupants of the shells, or to other organisms that accompanied the animals the shells of which remain; but considering that the bed lies immediately above and unconformably upon the oil-bearing series, as well as the fact that tests show a paucity of phosphates, one is almost bound to presume an adventitious origin for the petroleum, the absence of any cementing material in the shell-bed rendering it a very porous stratum for permeation by fluids.

The original specimens of this interesting shell-bed may be seen in the geological section at the South Kensington Museum.

Association of Salt with Petroliferous Strata.—Sodium chloride (common salt) is invariably associated with Russian oil deposits, as it appears to be with oil deposits in all parts of the world. Many attempts have been made to formulate theories of petroleum origin involving this ever-present salt, but without success; notwithstanding which, the opinion is still held that sodium chloride had something to do with it. It may be admitted, without prejudice, that common salt did have something to do with the formation of petroleum, though the theory just presented does not need to take notice of it.

It has been shown in various ways that the oil-bearing series of rocks about Baku were in all probability deposited in deep water; but this is inconsistent with such large quantities, and especially such variable quantities of common salt in the waters as are reported from different beds. It looks as if an adventitious origin must be found for the salt water. Three things deserve consideration in this connection. (1) No evidence exists of beds of salt and gypsum, such as are now forming in the shallow lagoons around the Caspian; (2) the salinity of the waters, as measured by the salinometer, does not represent common salt only (see Analysis of Waters, p. 93); (3) it is very doubtful whether any great quantity of water, salt or otherwise, can have been present in the true oil beds; it would so considerably reduce their capacity for oil.

The amount of salts (of all kinds, measured by a salinometer) found in different waters from the oil series varies between about 2 per cent. (like Caspian water) and 14 per cent., but a common amount is 10 to 12 per cent. The salinity of water from different wells, near together, at equal depths, often varies greatly, hence there is considerable probability that the variation is due to admission of water into the bore-hole from different sources—through faulty tubes or behind the casing. In some wells there is no question that this is the case. To these causes may be added the perhaps less common ones of incompleted bore-holes, and fissures resulting from landslips following the removal of large volumes of sand.

Salines abound in the neighbourhood of most Russian oil fields, wherever the low-lying ground is suitable for the accumulation of water. In winter the hollows get filled with water; it dissolves the soluble constituents of the rock it rests on and partly permeates, and becomes intensely salt. In the summer months the water is evaporated, and a white, glistening deposit of salt is left on the surface of the lake-bed. In the regions where strata reach the surface at a

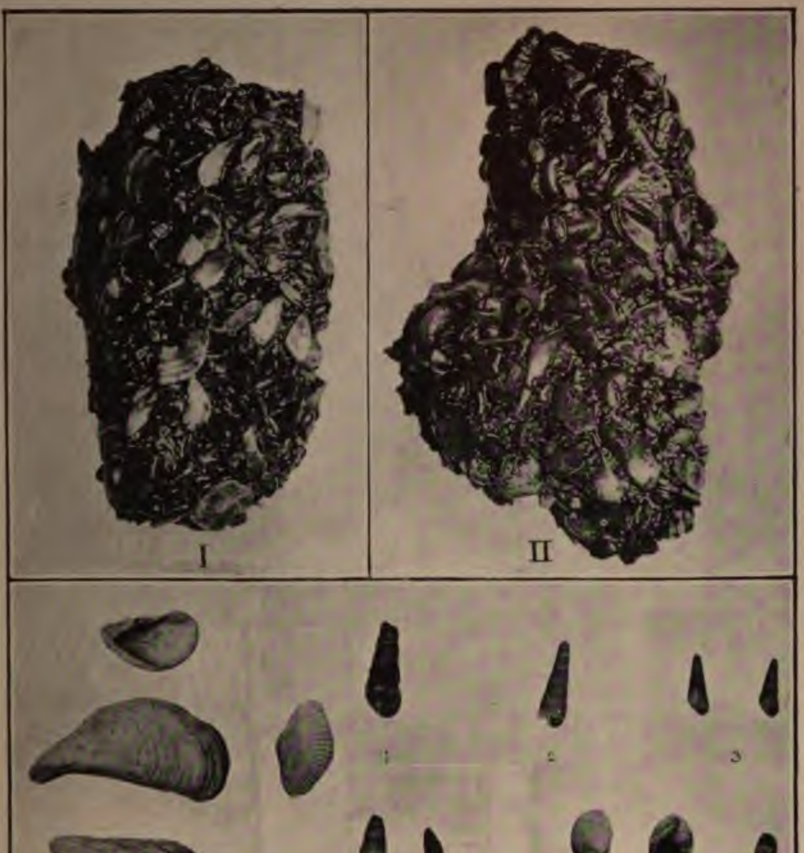

Fig. 15.—Details of Shell-bed in the Khordalan District.

I and II. Samples of the oil-impregnated shell-bed (natural size).
III. A few fair specimens (1, 2, 3, 4, 5, magnified 2 diameters; three on left natural size).
IV. Group of shells picked from a piece of the shell-bed (2 diameters).

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high angle, a deposit of white salt will often be found above them, the salt water continually creeping upwards to compensate evaporation, leaving its salt behind on the surface of the ground.

Waters from the Oil Strata.—Waters from the oil sands have peculiar and characteristic properties. No published analyses are known to the author, hence the insertion of the following notes. The quantity of water available for each of the subjoined analyses was about 650 c.c., a totally inadequate amount for the accurate estimation of a variety of things; but every possible care was taken to make the samples yield as much qualitative and quantitative information as possible, and the results will at least give a good general idea of the character of the waters:—

ANALYSES OF TWO SAMPLES OF WELL WATERS FROM THE SABOONTCHY OIL FIELD.

Sample 1.	*Sample* 2.
A little brown oil collects on the top after standing.	
Water, turbid after long standing, even gets more turbid, and a slight opaque film forms on the surface.	Water, turbid after standing several days; less so than No. 1.
Strong odour of petroleum.	Odour of petroleum.
Sediment, approximately 56 grains per gallon; settles slowly; consists of exceedingly fine siliceous matter.	Sediment, approximately 41 grains per gallon; light-grey colour. Water never quite clears, and does not even filter clear.
Neutral or slightly acid to litmus, alkaline to phenolphthalein.	Decidedly alkaline.
Free ammonia; rather less in filtered water.	Free ammonia; one-third the amount in filtered water.
Alkaline solution of potassic permanganate turns green (reduced to manganate). Unsaturated fatty acids converted into hydroxylated acids.	
Bulky precipitate with lime-water, which largely redissolves. Great excess of lime-water to get a permanent precipitate.	Same behaviour with lime-water as No. 1.
In estimating alkalies, a slight fibrous film forms on the solid residue. Darkens considerably on heating, and ultimately becomes white.	In estimating alkalies, the solid residue forms a white film with a stringy or matted appearance. Darkens, and ultimately forms a hard white cake.
No aluminium detected until after evaporation and ignition, therefore all in form of oleate or palmitate.	No aluminium detected until after evaporation and ignition.

	Parts per million.		Parts per million.
Free ammonia	14·5	Free ammonia	6·0
Albuminoid ammonia	2·1	Albuminoid ammonia	1·2
Total oxygen absorbed at 100° C.	222·0	Total oxygen absorbed at 100° C.	278·0

	Grains per gallon.		Grains per gallon.
Total solids dried at 130° C.	3269·50	Total solids dried at 130° C.	3187·70
Chlorine	1680·00	Chlorine	1484·00
Nitric acid	0·90	Nitric acid	1·06
Sulphuric acid	trace	Sulphuric acid	3·04
Carbonic acid ?	138·37 ?	Carbonic acid ?	130·37 ?
Iron	0·91		
Calcium	5·88	Calcium	4·92
Magnesium	17·53	Magnesium	6·31
Sodium	1155·85	Sodium	1052·50
Aluminium (+ little iron)	12·81	Aluminium	2·28
Oleic or palmitic acids	?	Oleic or palmitic acids	?
Sodium chloride	2768·45	Sodium chloride	2445·47
	= 4 per cent.		= 3½ per cent.

The estimation of carbonic acid is no doubt in error more than any of the other determinations, because the amount of saponaceous salts of aluminium and sodium, etc., was not properly appraised till too late.

Apparently, all waters that have been in intimate contact with petroleum-bearing strata contain salts of fatty acids, and give a turbidity with mineral acids, and the test is very useful as a simple indication of oil sources where water only is being bailed.

Other tests applied to or observations made on these waters may be more or less useful for the same purpose.

1. Where no oil can be observed in the water, the surface tension is very much greater than with ordinary water. Quite large drops of ordinary water floated on No. 2 after it had been filtered.

2. The water will not clarify by standing, and it can scarcely be cleared by filtering. The minute particles of silica or other material retain a pellicle of oil, which gives them sufficient buoyancy to float.

3. Bisulphide of carbon will extract fats. No. 1 yielded a yellowish solid fat; No. 2, a rather larger quantity of a white fatty-looking substance.

4. On treating a small quantity of the water (a mere film in a large flask does well) with strong sulphuric acid, a strong pungent odour of hydrochloric acid is observed, but also another, due to the presence of organic matter.

Natural Purified Oils.—The Surakhany gas sands, described fully in a subsequent paragraph, have for centuries been known to furnish a little highly refined volatile petroleum, of a straw colour, denominated "white oil," which commanded a ready sale at one time for medicinal purposes and branches in the early arts. The Surakhany product has a specific gravity of 0·780, and its composition is—

Benzine	48·9 per cent.
Kerosene	43·9 „
Other oils	7·2 „

Its highly volatile character, which causes a sensation of cold and pain when applied to the skin, has very likely led to its supposed curative powers, but in any case the extent of its use must have been strictly limited, as the quantity procurable is very small.

This naturally purified oil is not confined to the Surakhany district, for an almost identical description of petroleum is occasionally discovered on the Saboontchy oil field at variable depths. The problem of its unexpected appearance, especially in wells to the North of the Romany Lake, cannot be easily solved, but it is possible that "white oil" is much more widely distributed throughout the strata than is usually suspected, and that its collection is unobserved owing to the peculiar conditions of boring.

It is difficult to account for the presence of this "white oil," as its composition and properties are those of a distillation product, and it is by no means easy to imagine conditions under which distillation and condensation could take place.

General Surface Indications on Petroleum Territories.—Wherever the petroleum-bearing strata reach or nearly approach the surface of the ground, manifestations of such are generally indicated by a number of phenomena, which, to an experienced eye, may be usefully applied in forming an opinion of the value of the disturbed area. The interesting petroliferous strata of the Apsheron Peninsula, their continuation along the Trans-Caucasian Railway almost to Tiflis, and their extension along the Vladikavkas Railway, although prominently developed only at intervals, offer, in many places, exceptional opportunities for geological investigations of an extended character; for huge tracts of land where the oil-formations outcrop are denuded of all surface alluvial soils and are devoid of vegetation. The Puta district, situated about 20 miles to the south-west of Baku, on the shores of the Caspian Sea, furnishes an excellent example of what is usually found in the oil regions, for the oil strata reach the surface at a very acute angle, and the outcrop of the beds may be traced for miles on a level plain when riding over the country, each distinct stratum being identified by its colour, composition, exudations of oil, salt water, gas, or other features. Along some of the outcrops, the effusions of oil and gas have formed hills of the locally termed *kir* (which is simply oil deprived of its lighter volatile constituents and solidified, giving it a consistency and appearance of asphalt), which has accumulated to the extent of thousands of tons, and totally changed the physical appearance of the plain. In some parts the process may be seen still in active progress, the gas and oil bubbling through the kir, and rendering the mass so soft that it will not support the weight of a man's body. Other lines of strata are dotted with the so-called mud volcanoes, described later on; and again others are recognizable for long distances by their exudations of salt and various gases.

In the Trans-Caucasian provinces there are numerous outcrops of petroliferous strata, extending over many miles of territory, which have never been tested with an experimental boring; but as poor Tartar peasants who live a bare existence on these desolate wastes obtain a supply of fuel from shallow, hand-dug wells, there is little doubt that oil in larger quantities lies secreted there. The saliferous nature of the strata, and in many places the evolution of sulphur dioxide and other injurious gases, are responsible for the barren aspect of the oil-producing territories, which have generally an appearance little better than a desert, and are made almost uninhabitable on account of the rarity or total absence of fresh water and the means of procuring a livelihood; indeed, the only trace of vegetation is to be found on the slopes of hills, where an occasional patch of scrub attaches itself and provides food for the peasants' half-fed sheep. Many of these almost inaccessible spots, which can only be reached by long rides from stations on the railway, or far removed villages, over miles and miles of calcareous ground cut by deep ravines that have to be crossed often by a circuitous route, are known only by few. The heat is almost unbearable in summer, and the ground—for there is often no apology for a road even—is impassable for mud and slime in winter, and the best accommodation procurable after a most tiring day's journey is a shake-down in a Tartar hut, excavated in the side of a hill, generally well stocked with other visitors of a not very desirable description. As the ground is boggy and dangerous in many places during the winter, exploration must be conducted in the summer season, but it cannot be called a pleasant recreation to explore these barren territories, when the whole day must be spent in the saddle, under the fierce heat and terrific glare of the sun, with no particle of shade or relief to the eye procurable, and where the atmosphere is either sultry and suffocating or the winds cause the hot dust to be flung in blinding storms that envelop one in sand. Intending travellers to these almost unvisited areas should not fail, when undertaking an excursion, to provide themselves with food, as nothing of an appetizing nature is procurable anywhere; indeed, one glance at the unclean Tartars, who form little colonies in caves excavated in the sides of the hills, will suffice to drive away all desire for further acquaintance with them. The sheep-skin cloaks, the woolly busby worn above a fierce unkempt countenance, and the collection of knives and other warlike weapons slung around the waist, give to the males a ferocious look, only rivalled by that produced on the females by a covering of filthy coloured rags.

It is now purposed to examine each phenomenon connected with the distribution of oil in the strata separately and more minutely.

Escape of Petroleum Gas.—Exudations of petroleum gas are plentiful wherever the oil beds approach or reach the surface, and large gas-bearing deposits often fringe or accompany the oil-producing series. Historical records exist which show that the gas of the Surakhany district—an area fringing the south-eastern side of the Balakhany-Saboontchy oil field—has been known for very many centuries; and a temple of a curious style of architecture, situated within a few minutes' walk of the characteristic Tartar village of Surakhany, is said to have been one of the chief resorts of the Fire-worshippers, who flocked from all parts of India to perform a pilgrimage. The visitors continued to arrive in diminishing numbers until 1880, when the Russian Government put a stop to the entry of more pilgrims; but the devotees must have received a rude shock even before this date, on seeing a well-equipped petroleum refinery constructed under the very walls of the temple, utilizing for industrial purposes the sacred fire which they had travelled thousands of miles to worship.

A rough description of this renowned temple might here be conveniently introduced, for the building is not without great archæological interest. Around a courtyard of irregular and peculiar shape, the origin of which it is difficult to surmise, is a series of low cells, lighted only by a small opening, scarcely 5 feet high, that serves the purpose of a door, none of which communicates with the adjoining chamber. Above the entrance to each compartment is a well-preserved inscription in Hindustani or Sanscrit, whilst within the dismal unattractive cells will be found relics of a habitation that is impressive, on account of the simplicity and arrangement of the structure. One chamber, rather larger than the others, used by the priests to conduct therein their ceremonials and rites, contains an altar, to which the gas is admitted by orifices concealed in the masonry, and the lurid glare from this, when ignited, must have had an awe-inspiring effect upon the superstitious and ignorant devotees who attended the *séances*. Another cell, provided with stone rings carved from protruding blocks of stone, was evidently employed as a stable for the shelter of the pilgrims' animals; and yet another room was, according to the old Russian pensioner (a Crimean veteran) who acts as a guide and caretaker, utilized as a kitchen and bakery. The remainder of the chambers encircling the courtyard were apparently sleeping-compartments, and the stone slabs which either skirt the

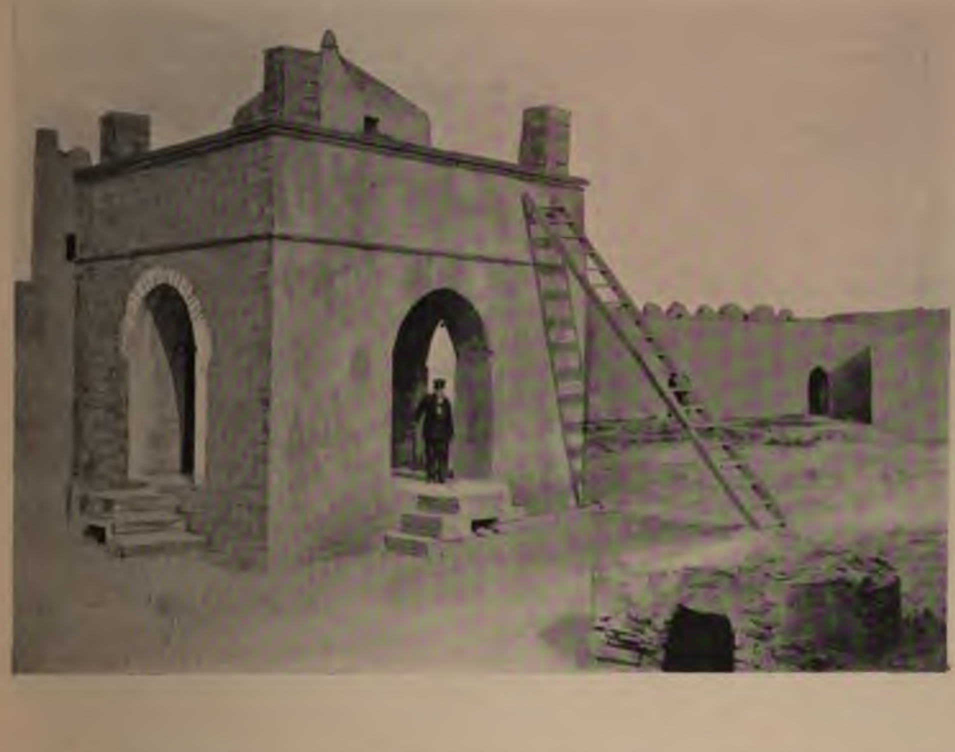

Fig. 16.—The Fire-worshippers' Temple at Surakhany

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walls or are placed in excavations in the structure were, presumably, the couches occupied by the believers when not busied in their devotions. As near as possible to the centre of the rude, heart-shaped courtyard a quadrangular building is located, arched on the four sides, and provided with a tower at each corner, to the summit of which gas is led by channels left in the stonework; and at a time when the gas pressure from the earth was much greater than it is to-day, the semi-transparent flames leaping up into the air must have created a profound impression upon those unacquainted with its origin. The entrance to the Surakhany temple is through a massive archway carved with clear inscriptions, and above this vestibule is a watch-tower, from which new arrivals could be welcomed.

This historical monument, standing on a site visited by Parsees for no less than 2500 years, should be preserved as a national ornament, and saved from the effects of vandalism and natural decay, from both of which it has suffered to a scandalous extent. Iron tubes have already been laid to replace the passages in the crumbling masonry, and one wall at least has been bulged by an explosion, following the incautious striking of a match in one of the gassy cells; but unless visitors' desire for notoriety is checked, the walls will be invisible for the initials of people who can find no other way of making themselves immortal.

Although the Surakhany gas fields were known so many years ago, little use has been made of them, and it is only within the last year (1903) that suggestions have been forthcoming to utilize the gas for power and light purposes in Baku and the oil fields. The peasants in the villages around Surakhany largely employ the gas for burning lime, as calcareous rocks are plentiful in the neighbourhood, cropping out in ridges at intervals. The Tartars declare that formerly a plentiful supply of gas could be obtained by digging a few feet into the fine, discoloured sand, with which it is associated; but they now have to excavate to a depth of 40–80 feet before they reach gas in sufficient volume to be of practical use. Their mode of procedure is to excavate a square hole large enough to admit the body of a man with ease, his ascent and descent being usually accomplished by means of footsteps dug in the sides of the pit; but his escape is always assured in the event of danger of asphyxiation following a sudden inrush of gas, by a rope secured to his waist, held by a man at the surface. When gas is reached, the pit is covered over, and passages or canals dug a few inches deep on the surface of the ground, and protected by stone slabs and soil, lead the gas to beneath conical heaps of limestone stacked for burning. The author, when first exploring these regions, prepared to ignite with a match one of these limestone stacks—for, when extinguished, the gas always escapes, there being no provision for storage or shutting off—but an alarmed attendant, whose language he did not understand, pulled him aside, and, with a low whistle and an expression full of meaning, pointed with his finger to the sky. He then lay flat on the ground, and ignited the gas by throwing several lighted matches into a recess beneath the limestone reserved for the purpose, thus escaping injury from the explosion that generally follows the ignition of a big pile. The fires, which are allowed to burn until calcination is completed, give a non-luminous flame, and are accompanied by much heat; and they are extinguished by suffocation with sand.

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A modern refinery was, many years ago, built by an oil-producer, named Cockereff, on the ground adjoining the Fire-worshippers' Temple, with the sole intention of utilizing the natural gas for fuel purposes; but it was found to be so unfavourably placed for obtaining the crude oil and delivering the refined products and residues that the place was abandoned, after the expenditure of an immense amount of capital. A boring sunk to a greater depth than usual, on Cockereff's (now the Baku Naphtha Co.) land, only last year (1902), encountered a very high gas pressure, that made it necessary to extinguish all the fires in the Surakhany temple to prevent a conflagration. The proprietors of the Baku Oil Co. are at length considering the advisability of laying a pipe-line to the oil fields, and using this gas on their properties, for the delay in bringing into practical use the millions and millions of cubic feet stored in many square miles of gas-beds is remarkable, and can only be explained by the unenterprising character of the Baku merchants.

The gas evolutions described are from beds that contain but little oil; and there are many square miles of such strata in other parts of the peninsula and the Caucasus, only awaiting the enterprise of the financier and the engineer. But distinct from these there are escapes of petroleum gas from outcrops of petroleum-bearing strata, which need some description. In the district to the west of Balakhany and Zabrat, and along the series of outcrops behind Bibi-Eibat and Puta, the gas exudations are very prevalent, and are not infrequently attended with a small discharge of heavy oil. The gas is often brought to practical use by the inhabitants for household purposes, a simple stove being improvised by arranging a few stone slabs over the crevices from which the gas issues; but more frequently these gas jets are looked on as curiosities, and only visited by curious sight-seers. In some districts the gas lies quiescent for months and even years, when suddenly, without any warning, a violent eruption takes place, almost equalling in vigour a volcano, creating consternation in the vicinity, and endangering the lives of the peasants. There are several mounds 100–300 feet high in the Puta district which occasionally exhibit activity in this way, one of which, in 1890, became ignited either by spontaneous combustion or by sparks arising from ejected stones striking each other. An enormous conflagration ensued, which lit up a considerable area brilliantly for several nights, and when the spot was afterwards visited by the author, there were no traces of escaping gas; but the effects of the eruption were indeed remarkable, and the condition of the ground dispelled any doubts being entertained as to its terrific nature. The calcareous sands, of which the hill was composed, were blown into huge cavities over the summit and some distance down the sides, many of which holes were large enough to admit a man's body, so that some idea of the volumes of gas that must have gushed forth and found relief in this way can be obtained. The intense heat of the fire was apparent from the fused and burnt state of the ground in the vicinity of the cavities.

In 1902, a similar eruption took place in the Kir-Maku region (to the west of Zabrat), and the escaping gas, which became ignited, led to the destruction of a herd of sheep that was grazing upon the rough scrub found in patches in that district. An account of this latter outbreak, which reached the English papers shortly after the Shemakha earthquake, was erroneously inserted in the column reserved for volcanic disturbances, and was connected with the West Indian disasters of that time.

The foregoing phenomena are not confined to the land, for whenever the outcrops occur beneath the sea, similar effects may be observed on the surface of the water. Marvin describes one spot in the sea off Bibi-Eibat, between Baieloff and Shikhoff promontories, where the petroleum gas reached the surface in such volumes that the violent ebullition set up had sufficient force to capsize boats that passed over the place. The same traveller also mentioned that if a light were applied to some parts of the sea in Baku Bay on a calm day, acres of water were covered with flame; but these effects are no longer visible, due, perhaps, to the active exploitation of the Bibi-Eibat oil field, with which the outcrops are in communication. Gas still, however, escapes in such volumes from the bed of the Caspian Sea, in a few places, that the surface of the water is violently agitated, rendering the spots visible from a long distance on a calm day; but it is stated by old observers that these phenomena are decreasing in extent as the active exploitation on the shore proceeds.* One of the attractions of Baku to curious sight-seers is to witness the sea on fire, either off Bailloff Point or near the coast of Holy Island, for which purpose steam-yachts may be hired or borrowed to convey visitors to the locality. On a calm night the disturbed spots are readily discernible, and when a piece of lighted tow is flung into the gas, ignition takes place, and the gas burns fiercely, scorching the paint on the sides of the vessel if allowed to approach too near. If the wind is not too high, the gas continues to burn for days, but in a high breeze and rough sea the flame is blown to one side and extinguished.

Mud Volcanoes.—The active little mounds to which the term "mud volcano" is applied are nearly always to be found wherever oil strata exist near to the surface of the ground, but they are in no way connected with volcanic action, and are simply the product of emissions of gas from oil or gas formations.

Wherever gas issues from a soft and damp stratum, a certain amount of ground is raised also, and this is deposited when the gas disengages itself. In course of time a conical mound of earthy material collects, at the summit of which a crater is generally visible, where gas, accompanied by mud, water, and sometimes oil, raised by the ascending gases, is found in a constant state of agitation. Some hills of considerable size have been produced in this manner, and when such is the case the upper portion is usually sprinkled with a large number of craters that are incessantly discharging gas and mud. To the west of Balakhany the oil beds reach the surface, and ejected mud commingled with accumulations of kir—the latter arising from discharges of heavy oil that has been deprived of its easily volatile constituents—have formed a hill of considerable magnitude, from the top of which an excellent view of the Apsheron Peninsula and the oil fields may be secured. At the summit of Bog-boga, as it is termed, there are several craters in constant activity, one of which is illustrated in the attached photograph taken by the author in the spring of 1903. The deposits of kir, especially to the north and north-east of Bog-boga, are now extensively quarried, and a local use is made of this material for manufacturing asphalt and covering the flat Eastern roofs of the Tartars' houses. There are many hills around Binegadi and Khordalan from the summit of which great quantities of salt water and mud are being discharged, and in some cases where the ejections of several craters have united, quite a wide stream of mud may be traced to the plain below. The whole of the Apsheron Peninsula and Holy Island, where the oil strata are exposed, furnish numberless examples of both large and small mud volcanoes, and it is stated that the Isle of Tcheleken, on the opposite side of the Caspian, is a sodden mass of kir and heavy oils resulting from ejections by gas.

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* The new wharf, built from the Schibaieff Petroleum Co.'s property, reaches almost to one of these evolutions of gas, and from this pier an excellent view of the phenomena can be obtained.

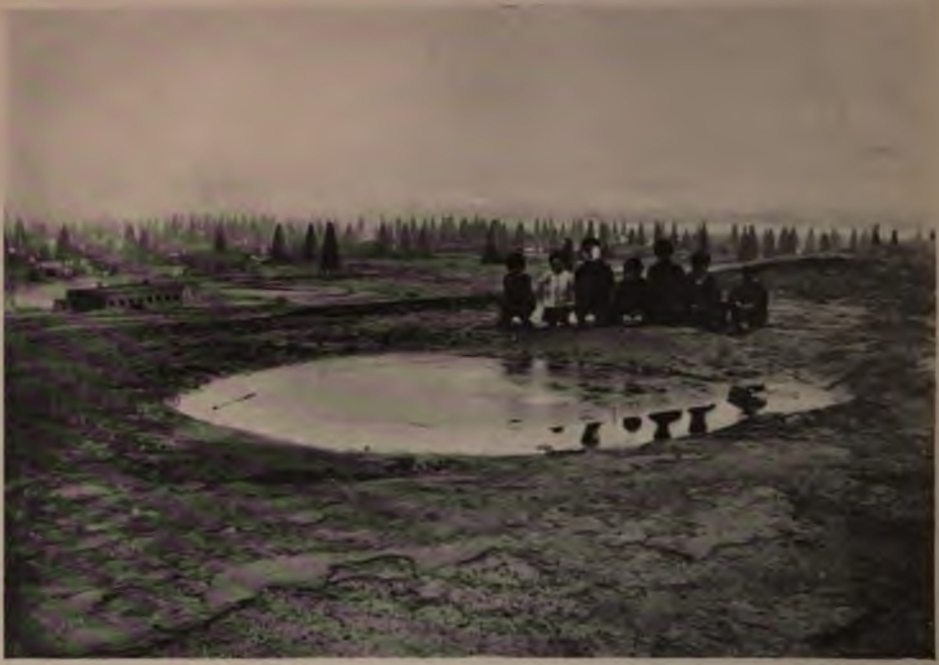

Fig. 17.—Mud Volcano at the Top of Bog-boga.

(The Balakhany-Saboontchy oil field in the distance.)

Escape of Sulphuretted Hydrogen and other Gases.—Sulphur in some form or other is nearly always associated with petroleum, and it is, doubtless, intimately connected with the formation of the oil, and has resulted possibly from the action of organisms such as recent chemical research, particularly in the Black Sea, has proved to be always in progress. Few wells are free from sulphuretted hydrogen (SH_2), although the pungent petroleum odour may disguise the disagreeable smell that always accompanies it when diluted with air, but in some instances sulphur dioxide (SO_2), is also evolved in large quantities, which can speedily be recognized by its stinging effect upon the nasal organs. In nearly all the valleys that sweep from the Balakhany oil field to Puta, evolutions of sulphurous gases are prevalent, and on a calm, hot day the atmosphere becomes so impregnated with sulphuretted hydrogen that it causes a feeling of oppression. In many places deposits of yellow sulphur will be found on the sides and exits of crevices from which the gases escape, a precipitation due apparently to the chemical action arising between sulphuretted hydrogen and sulphur dioxide, with formation of water and sulphur as occurs around volcanoes.

Sulphurous Springs and Waters.—Water saturated with sulphuretted hydrogen, recognizable by its dark colour and filthy odour, may often be seen exuding from oil strata wherever they are prominently exposed, and waters from *some* oil wells possess similar qualities, although the reason why some waters are, and others are not so impregnated is difficult to explain. Sulphurous springs are frequently an accompaniment to oil fields, and are also often struck when boring in a region not particularly rich in petroleum. All around the Baku oil fields, on the Grosny territories, upon Holy Island, and many other places where trial-borings have been made, sulphurous springs have been struck, but their appearance is not welcomed, as they often introduce difficulties in the boring, and lead to a waste of money and time.

In 1900, a well sunk to a depth of about 500 feet in an offshoot of the Kir-Maku Saline, behind Zabrat, encountered a strong sulphurous spring, which flowed incessantly between the tubes, but only from the inside when the plug was cleaned out. All attempts to pass the sulphurous source were fruitless, and eventually work was abandoned, and the water, which was remarkably free from salt, was delivered to the oil fields for boiler-feed purposes, by means of a pipe-line, through which it partly flowed by gravitation and was partly pumped. In the Grosny oil field, two flowing wells on plots 37 and 40, at a depth of 805 feet and 980 feet respectively, are discharging hot sulphurous water at a rate of about 150,000 gallons a day each, the streams from which have united and formed a miniature river, where not only do the local peasants perform their ablutions, but people from far around are attracted by the warm soft water that is supposed to possess qualities for strengthening weak constitutions, and relieving rheumatism and skin-troubles. The temperature of the water, viz., 104° F. and 117·5° F., or 40° C. and 47·5° C., must be due to some chemical action connected with the presence of the sulphur, for other waters, not far away, from equal and even greater depths exhibit neither such a high temperature nor such a character.

NOTES TO CHAPTER III.

Porosity of Sands.—Several points that have arisen in this and the preceding chapter call for a word of explanation; amongst others, that of the porosity of sands and sandstones.

Sands and sandstones are always to some extent porous, but the exact degree of porosity is dependent upon the special characteristics of particular varieties. In the Baku district the difficulty of estimating the porosity of the oil sands as they exist in nature is rendered almost impossible by the fact that immediately a bore-hole penetrates an oil source, and petroleum is yielded, the condition of the bed from which the oil is ejected or raised is changed. At first the stratum may not contain a high percentage of oil; but after long bailing, or an extended period of spouting, the underground conditions are materially changed for a considerable area and for a large radius around the well, either the density of the sand continually diminishes, and consequently the percentage of oil rises, or the area of minimum density increases as sand and oil are extracted.

A publication of the United States Geological Survey on the Motions of Underground Waters, by C. F. Slichter,* furnishes some important information bearing upon the porosity of various classes of sands and sandstones, and from this article may be drawn some useful hints that can be applied to Baku oil sands. A careful and interesting series of experiments showed that the porosity of a quartz sand varies from 30 to 40 per cent. by bulk; that a maximum of 47·64 per cent. was possible when all the grains were perfect spheres; and that a minimum of 25·95 per cent. was obtained when the grains were most inconveniently arranged for porosity. Irregularity of the particles did not greatly modify the porosity of a sand, as in nature the grains are not always deposited in the most compact manner possible. The author of the article confirms the views held by German and French scientists—namely, that pressure due to superincumbent strata does not have the effect of rendering sands impervious until a depth of 5 or 6 miles is reached, and that such pressures as result from the weight of a few thousand feet of superincumbent strata affect the porous qualities of sands to a very slight degree.

The investigations referred to above show that such porosities as 26 to 47 per cent. are not impossible in sands, and that one may assume them to be not unreasonable. Many sandstones are capable of absorbing from 10 to 20 per cent. of their bulk of water.

Mr. B. Thompson, in calling the author's attention to the above notes, remarks that the capacity of the Baku oil sands must have been enormously increased, if, as seems probable, immense quantities of organic remains were buried with the sands, as the capacity of the sand bed would be greater than sand with natural interspaces by the amount of space these organisms occupied before being sealed up, and before complete decomposition, *i.e.*, whilst they were in part solid. No amount of pressure subsequently applied would greatly diminish this capacity, owing to the gas pressure, which, within certain limits, increased as the pressure of over-strata increased. It is quite possible that the original presence of much organic matter affords an explanation of the huge capacity of some oil sands, greatly exceeding the maximum normal capacity for any fluid; and whilst agreeing with the theory of the origin of oil advocated, it offers a simpler explanation of some of the physical phenomena described, such as the easy movement or flow of sand.

Excitement.—The use of this word, it will be seen, occurs more than once in the volume to express a phenomenon for which the author cannot find a more appropriate expression. This excitement, resulting from various causes, very possibly largely affects the production of oil from a bore-hole, and influences the character of a well to no small degree; indeed, in one case already referred to, the excitement resulting from admission of oil into a disused well produced a fountain of oil.

When, in the Baku district, a fountain is flowing, the disturbance created in the oil stratum must be terrific, for the surface of the ground quivers for a radius of a quarter of a mile, and the noise produced by the violently expelled oil, gas, and sand can be heard for miles. It may be impossible to accurately describe the subterranean movements at such moments, but a little consideration will inevitably lead one to construct a mental picture of the kind of active changes taking place a thousand or more feet below the surface.

It is not improbable that the larger fountains in the Baku oil fields are partly due to the excitement or reaction occasioned by a flow of oil. At first, oil steadily overflows the casing, through supersaturation with gas; but immediately the heavy column of liquid is partly expelled, and a large part of the resistance removed, a violent rush of gas, carrying with it oil and sand, occurs towards the shoe of the tubes, with the result that exit is suddenly closed, and a violent check is momentarily imparted to the moving mass in the earth. For an instant the slow movement of a solid plug in the tubes prevents further admission to the tube; but as the upper pressure is still more relieved, and the pressure of gas below rises, the temporary resistance of the sand-plug is overcome, and the mass is ejected with terrific impetuosity up the tube. The sudden relief of pressure thus afforded causes another inrush of sand, and the action just described is repeated. There is, in fact, a constant water-hammer action going on in the sand stratum, which probably plays no small part in opening up oil ground for a considerable area around the bore-hole,—an area that would, but for this "excitement," remain unaffected.

* Water Supply and Irrigation Papers of the United States Geological Survey (No. 67) Washington, 1902.

CHAPTER IV.

DESCRIPTION OF AND STATISTICS RESPECTING THE MOST IMPORTANT CAUCASIAN OIL FIELDS.

Balakhany-Saboontchy-Romany-Zabrat Plateau.—Area and physical features—Roads and connection with Baku—Arrangement of strata.

Zabrat.—Unexpected meeting with oil at Zabrat at a moderate depth.

The Romany Lake.—Particulars of Lake-reclamation scheme—Terms of agreement with Moscow-Caucasian Co.

Bibi-Eibat Oil Field.—Position and extent—Natural features—Limited extent of exploitation—Addition to the field by reclamation from the Caspian: some particulars of the scheme—Exposure to violent storms.

Statistics relating to the Baku Oil Fields.—Production of oil: diagrams showing number of wells bailing, and average production, including and excluding fountains—Average depth of productive wells—Some interesting facts referring to the Baku oil fields.

Petroleum Companies exploiting Oil Lands in the Baku Oil Fields.—Baku companies—English companies—Causes of comparative want of success of English companies.

Division of Properties in the Baku Oil Fields.—The seven classes described.

Labour on the Baku Oil Fields.—Races and nationalities represented—Actual numbers down to recent date—Effect of employment of so many races as regards language, adaptability for work, and religious festivals.

The Grosny Oil Field.—Situation and character—Probably a considerable variety of features in the beds—Sketch of likely arrangement of the strata—Data from trial wells awaited—Contrast of beds with those of Baku—Yield of oil.

The Chatma Oil Field.—Position and means of access—Natural characteristics—Indications of oil—Brief account of geological conditions.

The Binagadi Oil Field.—Known, but not exploited before 1897—Character of oil—Arrangement of strata—Prospects of payable quantities of oil—Particulars of wells for the last few years.

The Puta Oil District.—Position and connection with Baku—Description of beds—Trial-boring in 1897—Government permission for boring refused up to present time.

Oil Fields of Small Extent.—Khiddirzindi: Drilling operations unsuccessful hitherto—Khordalan: Indications of oil common; one fountain met with, but insufficient data at present—Digya, Sarai, etc.: Large areas laid out and held under lease—Berekei: A fountain struck by Messrs. Nobel at 1400 feet, and more extensive works projected; some particulars; geographical situation—Tcheleken Island: Long known to be oil-yielding; at present but imperfectly explored; remarkable as almost only Russian source of paraffin series of hydrocarbons—Holy Island: An ancient oil source; trial operations of an unpromising character.

CHAPTER IV.

DESCRIPTION OF AND STATISTICS RESPECTING THE MOST IMPORTANT CAUCASIAN OIL FIELDS.

Balakhany-Saboontchy-Romany-Zabrat Plateau.—The oil field composing the four districts of Balakhany, Saboontchy, Romany, and Zabrat is situated on an almost level plateau about 175 feet above the Caspian Sea, or about 260 feet above the ocean-level. The total area of the plateau under exploitation, comprising the four districts, is no more than 4 square miles, 2560 acres, or 950 dessiatines, about 700 dessiatines or 73 per cent. of which is under active development. The oil field is connected with Baku, which lies about 8 miles to the south-west, by a railway having its destination in the village of Saboontchy; but there is also a first-class macadamized road leading from Baku, which is as largely used for the transport of oil-well requisites as the railway.

The first section of the oil field to attract attention was the district of Balakhany, where the oil-bearing formations outcrop, and where, not many years ago, good supplies of oil could be raised from small hand-dug wells. Saboontchy next fell into the hands of the oil exploiters, only to be followed after a time by Romany and Zabrat; but the exploration of the region has been very slow, owing to the lack of enterprise which characterizes the affluent capitalists, who content themselves with profitable results from proven lands, and show disinclination to invest money where success is not certain.

The plateau is sheltered on the north-east, east, south, and south-east by limestone rocks, which overlie the oil beds where they dip down acutely. On the west and north-west, the oil beds outcrop at the surface, and continue for many miles exposed on the surface of the ground. From Romany towards the west there is a steady rise of the strata, the dip being about 1 in 6; but at Romany the dip is great, and if the angle of dip shown by the overlying limestone is approximately correct, the angle is about 30°. A section of the ground in a direct line between Romany and Bog-boga, near the village of Balakhany, will be very nearly at right angles to the strike of the beds, and therefore will disclose the true dip of the formations.

There are eight well-defined oil zones, separated from each other by variable thicknesses of strata, that range between 70 feet and 150 feet; but below this the water sand is struck, which makes it difficult to ascertain what oil lies beneath. The series of sands which underlie the well-known oil formations have been penetrated to a depth of 400 feet, sometimes with good results and sometimes without any reward, and although many of the varieties of sand passed through are of the fine "blown" type, and deeply discoloured by petroleum, there appears to be much difficulty in overcoming the water and thoroughly testing the sources at such a great depth.

The Romany Lake.—A depression which flanges the southern side of this oil field has gradually come to be a natural depository for all the waste water and refuse from the properties located in the vicinity, and within a few years a small pond, which occupied the lowest points of the basin, has been converted into a lake with a superficial area of 160 dessiatines (432 acres). The level of the water in the lake, named the Romany Lake, stands 105 feet above sea-level, and as the depth varies from 14 to 28 feet, the deepest point of the lake lies 77 feet above the Caspian Sea level. The lake itself is estimated to contain about 263,000,000 cubic feet of water. As a large proportion of this expanse is undoubtedly rich oil-bearing ground, and, perhaps, the whole may prove equally valuable, the Government has been approached many times by financiers with schemes for removing a public nuisance, and reclaiming a huge block of rich oil-bearing territory. An arrangement was eventually arrived at, in 1901, with a group of Russian capitalists, trading under the name of the Moscow Caucasian Oil Co., who, in exchange for a lease of a large piece of ground on moderate terms, engaged to drain the lake by means of a subterranean conduit of a permanent description, as well as conduct some exploring work at certain points to ascertain the nature of the ground, for the information of the Government.

The work is now almost completed, by the excavation of a tunnel through the ridge at the east end of the lake, at a depth, in places, of 182 feet below the surface, to a point on the opposite side, from whence the water can flow by gravitation through an open conduit to the Caspian Sea. The tunnel is 8700 feet long, 7 feet high, 5 feet wide, and lined throughout with brickwork, and although a few points presented difficulties by the earth constantly caving, there were very few spots where more than ordinary precautions were needed, or where water appeared even in small quantities. The lake could have been much more economically and expeditiously emptied by pumping the water over the ridge; but this would not suit the requirements of the Government, who intend that the channel shall serve the purpose of a permanent drain to run off the waste water, etc., from the oil fields.

As the Romany Lake has been the recipient of all kinds of filth and refuse from a local population for a large number of years, the inhabitants of the village of Saboontchy, and residents of properties bordering the lake, will not have a very pleasant existence whilst the reclamation is in progress, especially during the heat of summer, and it may be advisable for early precautions to be taken by a sanitary board to minimize the effect of the work, and prevent an epidemic.

By the terms of agreement with the Government, the Moscow company was allotted 30 dessiatines of land, which they were empowered to choose, at a royalty of 25 per cent. of the production, upon which they must sink at least two wells per dessiatine, and pay on a minimum annual production of 400,000 poods per dessiatine. The contract also binds the company to bore seven trial

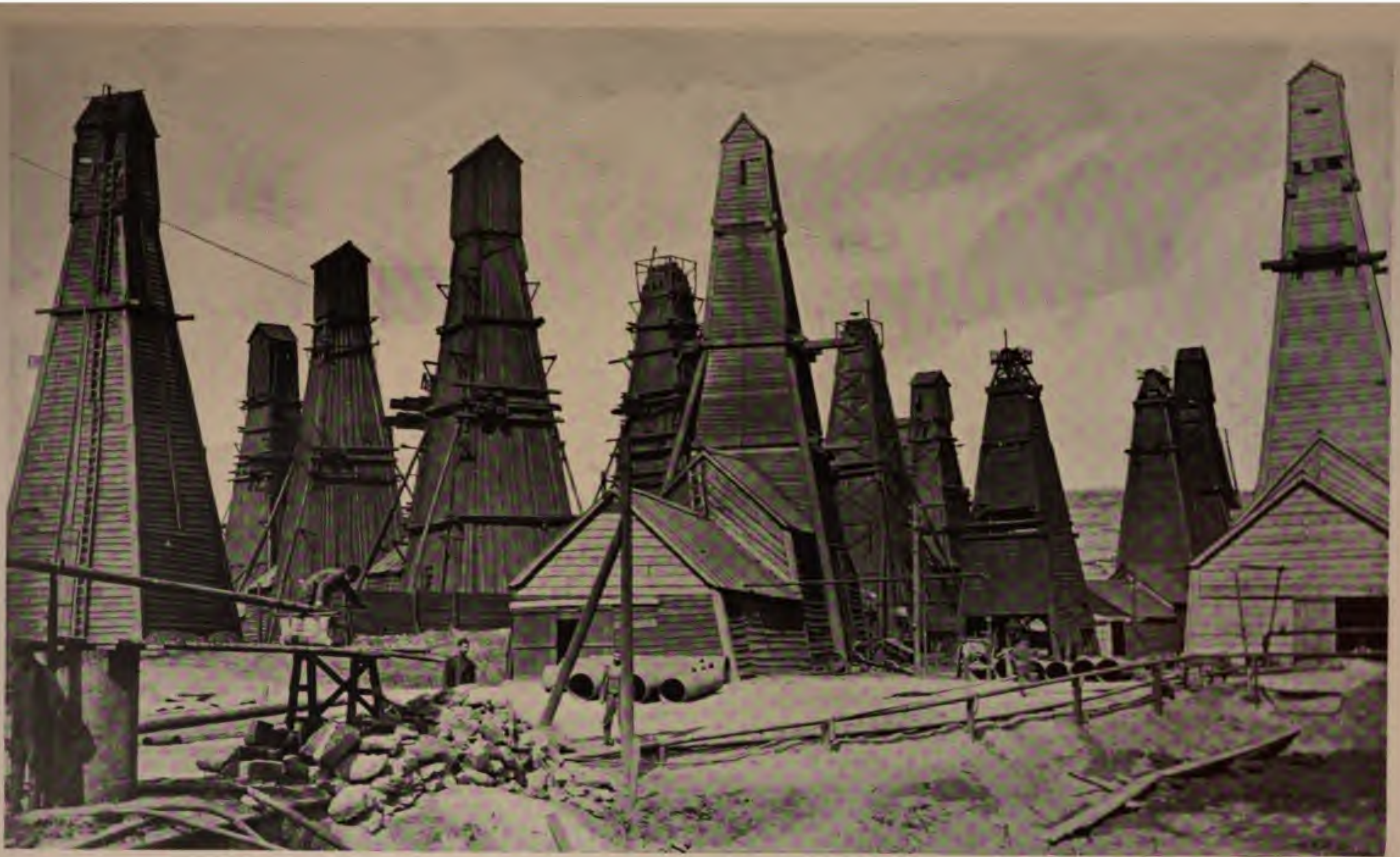

Fig. 18.—Characteristic View on the Balakhany-Saboontchy Oil Field.

[To face page 108

wells on the unproven and doubtful south-eastern part of the lake, to a depth of not less than 250 sagenes each, when the drainage of the lake is complete, for which purpose 7 separate dessiatines will be granted on terms similar to the other allotted plots, if oil is found. The Moscow company has already commenced seven borings on the submerged portion of two plots which they have chosen (19 P and 20 P) fringing the lake, where they will doubtless strike very prolific strata below 200 sagenes.

Zabrat.—Much to the surprise of many Baku oil men, a French company, exploring in the unproven Zabrat district, met with a strong flow of petroleum at a depth of little more than 700 feet, in close proximity to other wells which had proved unproductive. The official geological maps pointed to the unlikelihood of reaching oil at a reasonable and profitable depth; but the disclosure of oil at a shallow depth entirely upset the general theory of the oil formations. Several wells had previously been drilled to nearly 300 sagenes unsuccessfully; but the proprietors failed in their attempts solely because they delayed excluding the surface water, which disguised all traces of oil, until at a great depth cementation failed. The first oil in Zabrat is struck at 105 to 110 sagenes, a second bed is encountered at 125 to 130 sagenes, and a third stratum is reached at 140 to 150 sagenes; but the formations are not very prolific, and the production falls off very rapidly. The hard sandstone appears to be very prevalent in the Zabrat district, and it is impregnated with gas and oil to a more than usual extent, so that this may in some way account for the comparative paucity of oil, which is of a low specific gravity. No useful statistics have yet been prepared of this field, as the number of productive wells is small, but the average production will be low, as the outputs only range from 1000 poods to 3000 poods daily, after, perhaps, a primary spurt, and the tubes quickly collapse through the pioneers having completed their wells with a large diameter. The occurrence of the oil is shown to be erratic by the fact that one or two wells completed in good oil ground have dried up completely after a few weeks' steady bailing, whilst other wells, in close proximity, have continued to give a steady daily production of 2000 poods for many months. Natural expansion must embrace this new area, and a great deal is likely to be heard of Zabrat during the next few years.

Bibi-Eibat Oil Field.—The Bibi-Eibat oil field, which has been up to the present the only serious rival of the Balakhany-Saboontchy field, is situated about 3 miles due south from Baku, from whence all materials are carried by road, as there is no railway connection. The valley, which is fringed by the sea on one hand, and by a semicircle of almost precipitous cliffs behind and around, has an area of about 1·6 square miles, *i.e.*, 1024 acres, or nearly 400 dessiatines, of which only about 40 per cent., or 160 dessiatines, are under exploitation, but it will shortly be increased by the addition of another 810 acres (300 dessiatines), that are to be reclaimed from the sea.

The formation of the Bibi-Eibat field partakes of the character of a regular cone, the apex of which, strangely, appears to be situated near plot xix., which belongs to the Russian Petroleum and Liquid Fuel Co. On all sides, except, perhaps, the sea quarter, the strata descend; and where the limestones are reached which cover the oil series, steep cliffs are produced that might easily be mistaken for faults by a casual glance. The huge limestone masses which surround the valley produce an imposing spectacle that strongly impresses all new visitors. The oil strata do not slope acutely on the sea quarter, for there are evolutions of petroleum gas in the sea itself, and it is reported that at one time such escapes were more prevalent. The Bibi-Eibat oil field has not been explored to the same degree as the Balakhany district, and is in a much more modern period of exploitation, so that there is not the same amount of evidence collected as in the former field. Up to the present time the oil beds have never been completely pierced, and the water sand that has caused such consternation in the Balakhany-Saboontchy field has not yet been encountered. Five or six oil strata only have yet been penetrated, and it is quite within the range of possibility that deeper ones than these will never be reached or tested on the slopes of the anticline, on account of the excessive cost of completing wells in Baku at a depth exceeding 300 sagenes (2100 feet), where a slight accident or an unproductive or but slightly productive well may mean the loss of 100,000 roubles (over £10,000).

Frequent suggestions have been made in the proper quarters to consider the reclamation of some of the land on the shore at Bibi-Eibat, but this involves a much more extensive and elaborate scheme than the comparatively small Romany Lake drainage, and the Government has wisely decided to recover the whole strip of sea-bed from Baieloff Point to the Shikhoff promontory, and make each lessee bear an equal share in the expenses of the movement, irrespective of the position of his plot. The Russian Government invited offers, in the summer of 1901, for plots of 4 dessiatines each on the proposed site, at a royalty of 40 per cent. of the production, and with a minimum annual output of 300,000 poods per dessiatine, implying at the same time that offers from reputable firms already engaged in the industry would receive priority, but if some plots are not taken up at this price, the amount of royalty may be reduced to 35 per cent. or less, but in no case will less than 25 per cent. be accepted, nor will exploitation be allowed anywhere until the whole of the blocks are leased, when operations will be commenced on the whole field simultaneously. When all the 4-dessiatine plots have been disposed of, every person receiving an intimation that his offer is accepted must pay to the Government a sum of money approximately estimated at 120,000 roubles, which will be spent on works connected with the recovery of the land from the sea. Most of the deposit will be returned by crediting the lessee when the royalties become due, but a small proportion will be detained as a guarantee of the fulfilment of the obligations stipulated in the contract.

Calculated on the basis of a minimum production, the output from the land absorbed by the Bibi-Eibat extension scheme alone represents an increase of nearly 100,000,000 poods of oil annually; but actually the extracted oil will probably be three or four times this quantity if the authorities insist upon the exploitation of the whole 300 dessiatines at the same time.*

The reclamation of the Romany Lake and the sea-shore off Bibi-Eibat

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* In 1901 the average production *per well* in Bibi-Eibat was 931,000 poods, three times the stipulated minimum output per dessiatine, and in 1902 the average yield per productive well was 944,000 poods.

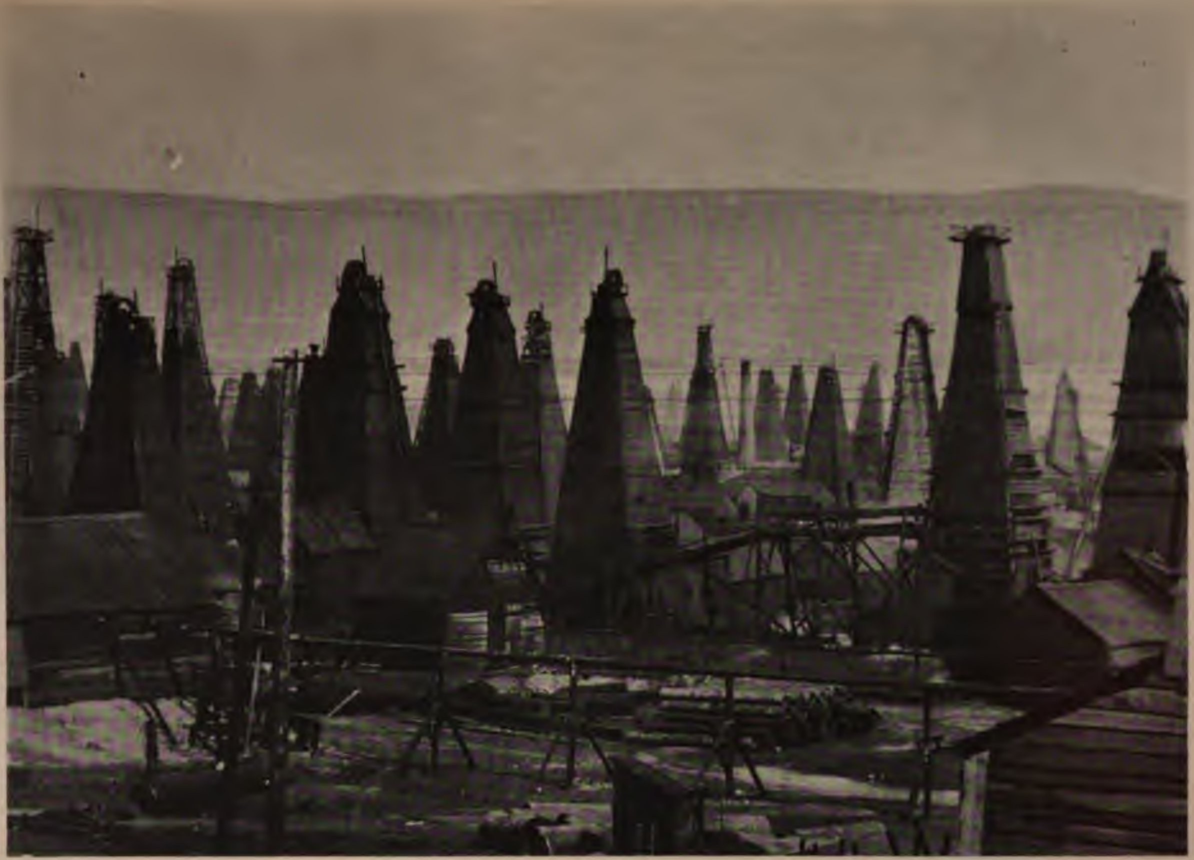

Fig. 19.—Bibi-Eibat Oil Field.

(View from Plot 57 B.-E. looking towards Plot XIX.)

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TILDEN FOUNDATIONS.

will represent the recovery of two very large oil fields within the next few years, and it is hoped that the Government will not throw open these new territories without making suitable provision for drainage canals, pipe-line tracks, and roads for easy access to all plots, lack of which is seriously felt on the older oil fields.

The position of the Bibi-Eibat oil field exposes it to most violent storms, which convey tons and tons of sand, pebbles, and dirt from the high-lying ground which surrounds it, and renders life most disagreeable until the wind subsides. The peculiar formation of the valley also causes violent cross-currents and changeable winds to sweep the field, which are a source of great anxiety to every one when a fire originates on the field, as no one can tell when a deviation of the breezes may carry the burning woodwork to the least expected spot. The proximity of the sea is extremely useful, for it provides an endless supply of boiler-feed water, water for fire purposes, and watering the roads, besides being a convenient medium for the cheap conveyance of the crude oil to the Blacktown refineries.

Statistics relating to the Baku Oil Fields: Production of Oil.—For the purpose of easy comparison, the statistics of the Baku oil fields—Balakhany, Saboontchy, Romany, Zabrat, and Bibi-Eibat—will be grouped together in graphic form, and given separately in tabular form.

Tables VI., VII., VIII. give for each year since 1892—

(*a*) The total number of wells which gave a production of oil.
(*b*) The total production of oil in poods.
(*c*) The average production of oil per well.
(*d*) The number of productive wells, exclusive of fountains.
(*e*) The total production of oil from bailing wells alone.
(*f*) Average production of oil per bailing well.

TABLE VI.

BALAKHANY.

Year.	Number of productive wells.	Total production in poods.	Average production per well.	Exclusive of fountains.		
				Number of wells.	Bailing production in poods.	Average production per well.
1892	169	57,472,460	340,073	169	57,472,460	340,073
1893	175	57,833,430	330,400	174	57,599,430	331,031
1894	193	59,035,523	305,882	193	59,035,523	305,882
1895	230	67,558,297	292,579	230	67,558,297	293,579
1896	290	85,647,175	295,335	289	85,499,175	295,844
1897	387	96,315,225	248,876	387	96,315,225	248,876
1898	485	108,836,439	224,611	482	107,396,434	222,814
1899	610	114,854,151	188,285	609	114,844,151	188,578
1900	736	124,680,087	169,402	736	124,680,087	169,402
1901	775	117,783,832	151,979	775	117,783,832	151,979
1902	720	100,504,267	140,978	720	100,504,267	140,978
1903						
1904						
1905						

TABLE VI.—*continued.*

SABOONTCHY.

Year.	Number of productive wells.	Total production in poods.	Average production per well.	Exclusive of fountains.		
				Number of wells.	Bailing production in poods.	Average production per well.
1892	230	154,737,100	672,800	208	116,434,720	554,974
1893	224	146,288,674	648,600	204	118,324,674	580,022
1894	260	143,029,202	550,100	254	132,891,202	523,093
1895	281	151,331,605	538,546	262	132,743,605	506,655
1896	325	152,674,160	469,766	313	138,557,160	442,674
1897	386	166,928,593	432,457	374	151,512,593	405,113
1898	457	179,828,697	393,498	437	159,461,697	364,912
1899	543	230,757,289	450,750	533	195,022,289	365,895
1900	665	251,634,159	378,096	660	240,488,159	364,376
1901	780	295,254,315	378,531	761	257,300,215	338,108
1902	751	267,159,044	355,737	738	257,358,544	352,789
1903						
1904						
1905						

ROMANY.

1892	29	41,041,380	1,415,200	24	20,926,380	871,932
1893	33	73,156,364	2,216,500	22	29,126,364	1,323,925
1894	52	61,701,100	1,186,500	41	34,530,047	842,196
1895	62	111,408,645	1,796,913	47	42,981,645	914,503
1896	84	78,088,324	929,622	68	57,434,324	844,622
1897	103	96,702,454	912,287	93	66,309,454	713,004
1898	113	100,523,699	889,590	99	69,081,699	697,794
1899	138	98,581,782	714,360	130	74,919,782	576,306
1900	185	114,835,986	620,734	177	84,763,386	478,889
1901	213	124,156,817	582,895	205	102,158,879	498,336
1902	219	139,943,833	639,013	204	101,396,033	497,039
1903						
1904						
1905						

TABLE VII.

BIBI-EIBAT.

1892	20	33,262,900	1,663,150	15	15,928,080	1,061,872
1893	26	47,494,729	1,826,700	20	10,514,729	525,736
1894	27	33,785,249	1,251,300	15	9,245,249	616,350
1895	31	47,128,073	1,520,260	23	21,346,073	928,090
1896	35	69,855,123	1,995,860	28	17,787,123	635,254
1897	38	62,514,479	1,645,117	27	19,478,479	721,425
1898	48	96,526,783	2,010,972	33	36,628,783	1,109,963
1899	58	80,840,807	1,393,807	55	59,759,807	1,086,541
1900	112	109,207,063	975,000	100	82,592,763	825,927
1901	143	133,613,181	934,358	137	95,546,581	697,420
1902	135	127,433,285	943,950	121	81,347,585	672,294
1903						
1904						
1905						

Table VIII. gives particulars of production from the whole Apsheron Peninsula (Balakhany-Saboontchy-Romany-Zabrat-Bibi-Eibat grouped together.)

TABLE VIII.

APSHERON PENINSULA.

Year.	Number of productive wells.	Total production in poods.	Average production per well.	Exclusive of fountains.		
				Number of wells.	Bailing production per well.	Average production per well.
1892	448	286,513,843	639,500	416	210,761,640	506,638
1893	458	324,763,197	709,089	420	215,565,197	513,250
1894	532	297,551,021	559,006	503	235,702,021	468,592
1895	604	377,426,620	624,878	562	264,629,620	470,871
1896	734	386,264,782	526,246	698	299,277,782	428,764
1897	917	422,460,751	460,698	881	333,615,751	378,678
1898	1107	485,943,348	438,973	1055	372,796,348	353,361
1899	1357	525,247,415	387,065	1334	444,759,415	333.403
1900	1710	600,763,812	351,323	1685	532,930,912	316,279
1901	1924	671,276,263	848,896	1889	573,157,628	303,418
1902	1840	636,831,120	346,103	1798	542,094,852	301,497
1903						
1904						
1905						

Diagrams Figs. 20, 21, 22 show respectively the number of wells bailing, the average production per well per annum (inclusive of fountains), and the average bailing production per well per annum (exclusive of fountains), in the four districts under consideration.

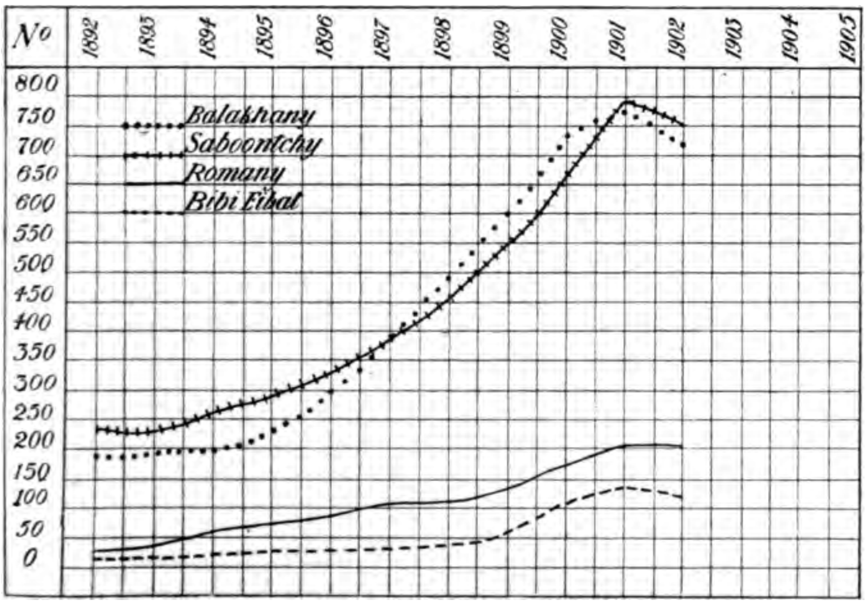

Fig. 20.—Number of Wells in Exploitation.

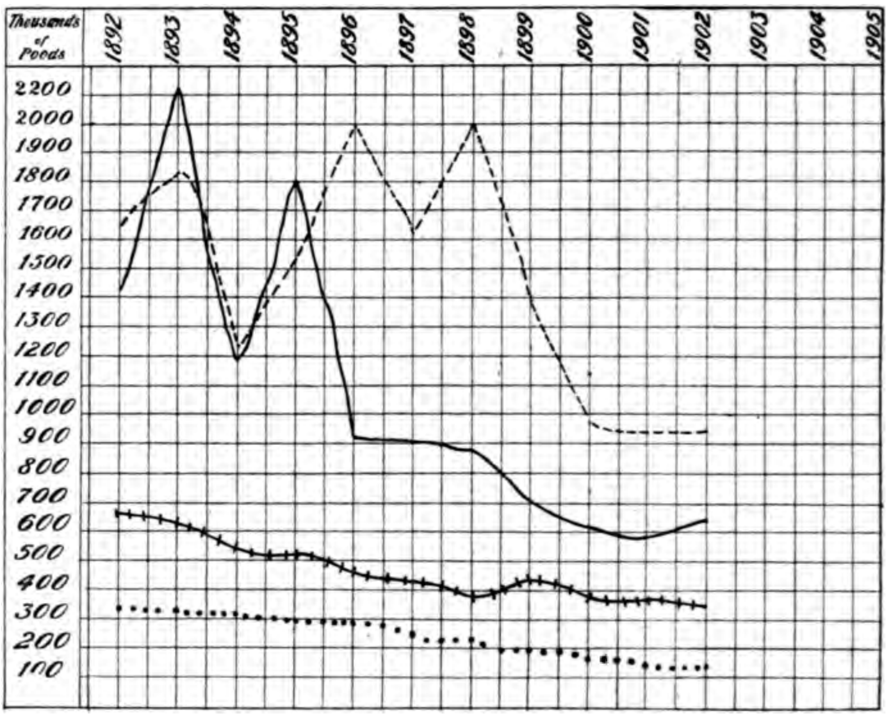

Fig. 21.—Average Total Production per Well per Annum.

. . . . . Balakhany. +++++ Saboontchy. —— Romany. - - - - Bibi-Eibat.

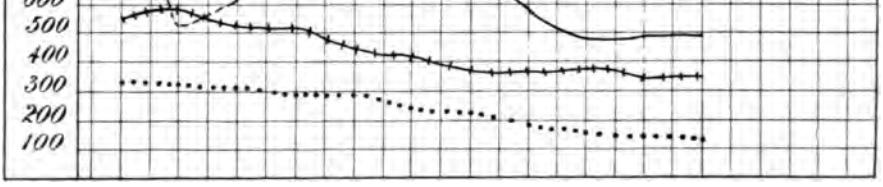

Fig. 22.—Average Bailing Production per Well per Annum.

. . . . . Balakhany. +++++ Saboontchy. —— Romany. - - - - Bibi-Eibat.

In the foregoing tables the number of wells includes—

(*a*) All that were completed in some previous year.

(*b*) All that became unproductive during the year.

(*c*) All that were completed in the year specified.

(*d*) All that were stopped for a time on account of accidents, fires, etc.; and the average period of bailing does not probably exceed 8 months per well, so that the rate of output per well exceeds the figures named.

Table IX. gives the number of old and new wells (with their total production and average yield) producing each year since 1892, and an approximate average annual rate of output would be obtained by assuming the old wells to have been bailed 9 months and the new ones 6 months.

TABLE IX.

PRODUCTION FROM OLD AND NEW WELLS FOR EACH YEAR SINCE 1892.

Description.	Year.	Number of wells.	Total production of oil in poods.	Average production per well.
Old wells.	1892	365	223,800,000	613,000
	1893	390	257,913,000	661,000
	1894	442	252,108,000	570,000
	1895	517	265,705,000	514,000
	1896	593	281,421,900	474,000
	1897	677	318,662,000	477,000
	1898	833	324,055,000	389,000
	1899	1012	429,682,000	424,000
	1900	1263	437,997,000	346,000
	1901	1544	491,894,000	319,000
	1902	1595	521,076,000	327,000
	1903			
	1904			
	1905			
New wells.	1892	83	62,700,000	756,000
	1893	68	66,849,000	983,000
	1894	90	45,442,000	505,000
	1895	87	111,721,000	1,284,000
	1896	141	104,812,000	743,000
	1897	224	103,064,000	460,000
	1898	284	161,888,000	590,000
	1899	345	95,564,000	276,000
	1900	447	162,766,000	364,000
	1801	380	179,382,000	472,000
	1902	245	115,452,000	471,000
	1903			
	1904			
	1905			

Old wells,—those which were completed in a former year.

New wells,—those which were completed during the year specified.

Old wells were bailed, on an average, 9 months in the year. New wells were bailed, on an average, 6 months of the year.

The first wells sunk in a new district naturally secure the cream of the oil strata they tap for a very considerable area around, and the output per well far exceeds that in older regions, so that to compare the actual productiveness of different fields, the statistics should be compiled for equivalent periods of exploitation. The diagrams show clearly the steady decline in production on the largely exploited areas of Balakhany and Saboontchy (compare diagrams) due to the removal of oil and drainage of the beds, whilst the enormous fall of yield in the Romany wells, notwithstanding a *slow* increase in the number of borings, rather indicates that the value of this newer field has been largely over-rated. The diagrams also exhibit the great fluctuations of average production during the early life of the two comparatively new districts, Romany and Bibi-Eibat; but Balakhany and Saboontchy displayed something very similar in their early life, and it is only when exploitation has developed that the curves show a regularity, which by degrees assume a steady decline as the oil sources become drained.

Diagram Fig. 23 shows graphically the average depth of productive wells over the same period as the bailing is traced, and divulges the fact that whilst the average depth of Balakhany and Saboontchy wells has increased very little during the last year or two, the depths of Romany and Bibi-Eibat wells have increased enormously. This fact only serves to emphasize the importance of the impression already stated, although few people will admit it, that Romany is not likely to develop into such a valuable oil field as the old Balakhany and Saboontchy regions were at equivalent periods of exploration. Suspension of boring on the Bibi-Eibat oil field rather modifies such an inference with regard to that field.

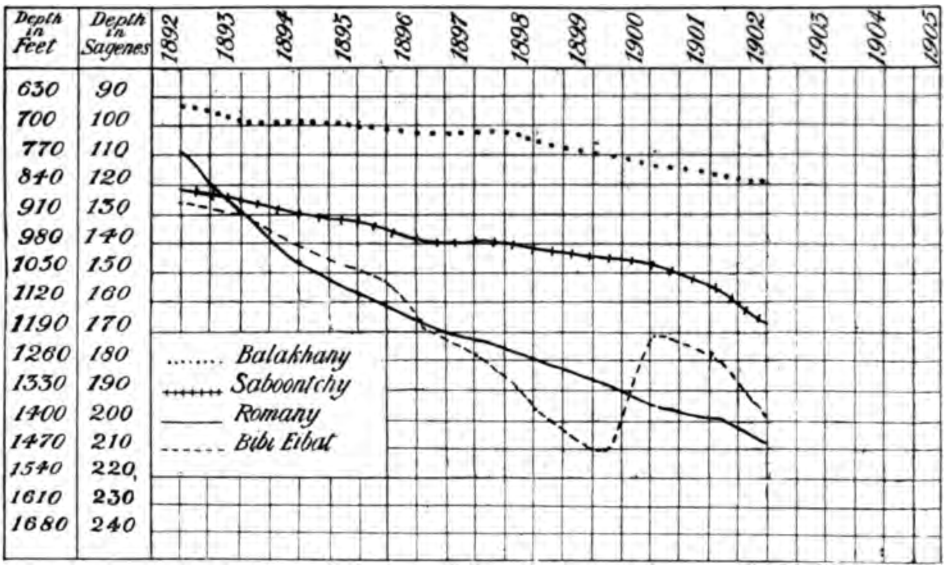

Fig. 23.—Average Depth of Wells per Annum.

TABLE X.

AVERAGE DEPTH IN SAGENES OF PRODUCTIVE OIL WELLS.

Year.	Balakhany.	Saboontchy.	Romany.	Bibi-Eibat.
1892	93·1	120·5	109·8	125·7
1893	96·8	122·9	128·6	129·8
1894	97·4	129·3	145·3	140·0
1895	98·4	131·3	154·7	147·1
1896	101·6	138·7	163·8	163·9
1897	102·4	137·2	171·0	177·3
1898	105·1	141·1	178·0	195·3
1899	109·3	144·2	185·7	200·0
1900	113·6	147·5	193·4	171·3
1901	116·0	155·9	199·8	178·2
1902	119·4	165·8	207·0	198·0
1903				
1904				
1905				

Between 1889 and 1903, 508,800 sagenes, or 674 miles, of boring have been performed in the Baku oil fields, and each year from 40,000 to 80,000 sagenes (50 to 100 miles) are added to the above amount. During the same period about 24,500,000 poods, or nearly 400,000 tons, of iron have been sunk into a few square miles of territory near Baku, the pecuniary value of which is about £3,500,000, whilst over £500,000 worth of labour must have been expended on the iron before it was lowered into the ground as casing. From 1,750,000 to 3,000,000 poods—say 28,000 to 48,000 tons—of iron are annually sunk into the earth, and are irrecoverable.

In 1902 the dimensions of the Baku productive wells were as follows :—

113 wells from 6 inches to 10 inches diameter = 6·2 per cent.
914 „ 10 „ 15 „ = 49·7 „
630 „ 15 „ 20 „ = 34·2 „
183 „ 20 „ 26 „ = 9·9 „
1840 100·0

Petroleum Companies exploiting Oil Lands in the Baku Oil Fields.—The attached list gives, in alphabetical order, the names of all the Baku producing companies in 1901 and 1902, at the side of each being noted the total production and the amount of fountain oil obtained in the years 1901 and 1902.

TABLE XI.

Name of company exploiting oil.	Production, 1901.		Production, 1902.	
	Total production.	Fountain oil.	Total production.	Fountain oil.
1. Abiantz and Co.	678,000		766,034	
2. Avakoff, M. X.	2,075,000		2,014,000	
3. Adamoff, A. E.	1,732,000		4,375,000	
4. Adamoff, D. E.	896,000		1,480,000	
5. Adamoff, E. D.	1,639,000		1,262,000	
6. Adamoff, A. Ab.	577,000		458,000	
7. Adamoff, Al. Eb.			3,000	
8. Adamoff Bros.				
9. "Agbur" Co.	1,522,000		1,400,000	
10. Akopoff, Aslan	878,000		569,000	
11. Akopoff and Adamoff	177,000			
12. Amilakhvari	346,000		241,101	
13. Annonim Co.	171,000			
14. Antonoff, A. E.	1,571,000		1,543,000	
15. Astikhik Oil Co.	553,000			
16. Ashourbekoff Bros.	255,000		465,000	
17. Apsheron Oil Co.	1,801,000		1,559,000	
18. "Arai" Oil Co.	297,000	100,000		
19. "Aragats" Co.	1,116,000		988,000	
20. "Ararat"	1,098,000		693,000	
21. Arshalius Oil Co.	1,196,000		3,176,000	
22. "Araks"	556,000		309,000	
23. "Aramazd" Oil Co.	13,662,000		10,295,000	1,905,500
24. Arafeloff, G. M., and Co.	1,889,000		1,258,000	
25. Assadulaieff, Shamsi	7,118,000		17,941,000	10,240,600
26. Astrakhan Oil Co.	1,338,000		1,242,000	
27. Aslanoff			726,000	
28. Baku Oil Co.	56,587,000	15,476,000	34,129,000	1,192,000
29. Baku-Russian Petroleum Co.	25,946,000	8,570,000	22,298,000	
30. Balakhany Oil Co.	3,653,000		1,087,000	
31. "Bakht" Co.	1,636,000		1,307,000	
32. Baku Oil and Industrial Co.	4,238,000	10,000	3,153,000	22,000
33. Benkendorf and Co.	6,685,000		7,312,000	
34. Blazy, All.	142,000		179,000	
35. Baku Pump Station				
36. Balakhany Oil Co.	1,615,000		2,921,000	
37. Balakhany Syndicate			28,000	
38. Balakhany-Saboontchy Oil Co.	415,000		737,000	
39. "Bibi-Eibat" Co.	209,000		26,000	
40. Bibi-Eibat Oil Co.	7,258,000		170,000	
41. Booniatoff Bros.				
42. Caucasian Oil Co.	6,382,000		6,526,000	
43. Caspian and Black Sea Co.	50,691,000	1,491,000	55,929,000	10,782,000
44. Caspian Co.	40,007,000	5,003,000	37,379,000	
45. Chernoneboff	78,000		1,323,000	
46. Djabaieff and Co.	14,000			
47. Dembot, I. C.	919,000		550,000	
48. Dochar	618,000		777,000	
49. Dadiani	1,403,000		1,831,000	
50. Dadasheff (Doozl)	359,000		485,000	
51. Eastern Oil Co.	1,447,000		525,000	
52. European Petroleum Co.	17,137,000		14,171,000	
53. Egiazaroff	865,000		761,000	
54. "Eraz" Co.	357,000			
55. "Faros" Co.	1,593,000		1,494,000	

TABLE XI.—*continued.*

Name of company exploiting oil.	Production, 1901.		Production, 1902.	
	Total production.	Fountain oil.	Total production.	Fountain oil.
56. Gagen and Ter-Akopoff	329,000		339,000	
57. Galperin, E. G.	609,000		625,000	
58. Galperin and Co.	1,012,000		654,000	
59. Gagen, T. and E.	2,268,000		1,667,000	
60. "Gokhtan"	530,000		466,000	
61. Gukasoff, P. O. (Zabava)	4,619,000		2,386,000	
62. Grosberg, M. E.	1,036,000		778,000	
63. "Kavkas" Co.	4,360,000	504,000	3,671,000	
64. Kalantaroff, M. A.	1,853,000		1,862,000	
65. Kalantaroff Trading House	2,671,000		12,644,000	5,985,000
66. "Kama" (Metrofanoff)	2,803,000		3,332,000	
67. Kaiser	177,000			
68. Karai	67,000		248,000	
69. Kolmanoff and Nazaroff			197,000	
70. Kolesnikoff Bros.	1,939,000		1,866,000	
71. Kholyaro	182,000		187,000	
72. "Korun" Co.	245,000		218,000	
73. Krasilnikoff Bros. and Co.	48,000		1,431,000	1,358,000
74. Krasilnikoff Bros.	3,385,000		2,208,000	
75. Kvaristrem	537,000		320,000	
76. Kvaristrem and Co.	4,018,000	1,443,000	3,718,000	
77. Krasilnikoff, N.	1,342,000		1,409,000	
78. Koosis and Teofilaktos			38,000	
79. Lazareff Bros.	553,000		276,000	
80. Leskevich	76,000			
81. "Loosnyak" Co.	242,000		201,000	
82. Manafoff	1,196,000		884,000	
83. Mantasheff and Co.	56,966,000	16,531,000	49,949,000	13,530,000
84. Markaryants	99,000		64,000	
85. "Maigooli"	3,000			
86. Melikoff, A. C., and Co.	3,106,000		2,930,000	
87. Meerzoeff Bros.	23,660,000		18,914,000	
88. Meloff, A. E., and Tairoff	533,000		602,000	
89. Mirza Avakoff and Kar	230,000			
90. Mikirtoomoff			113,000	
91. Mnatskanoff	331,000		255,000	
92. "Molot" Co.	11,000		6,000	
93. Nadejin	76,000			
94. Nazaroff	414,000			
95. Nadjaroff, E. A.	114,000			
96. Nabatoff and Partners	2,006,000		1,103,000	
97. Naftal Oil Co.	3,719,000		3,068,000	600,000
98. Nagieff, Musa	15,602,000	11,059,000	8,866,000	
99. "Neft" Co.	1,210,000			
100. Nobel Bros. and Co.	81,352,000	14,731,000	78,102,000	8,400,000
101. "Nor, Masis"	89,000		53,000	
102. "Orion" Co.	1,004,000		256,000	
103. Pitoeff and Co.	16,568,000	4,885,000	19,422,000	5,660,000
104. "Petrol" Co.	1,897,000		1,824,000	
105. Pollack Trading House	1,131,000		1,281,000	746,000
106. Pogosoff			26,000	
107. Popoff and Co.	2,551,000		2,204,000	
108. "Radoga"	2,788,000	2,256,000	2,019,000	
109. "Russia" Co.	523,000		692,000	
110. Russian Petroleum and Liquid Fuel Co.	33,866,000		30,142,000	

TABLE XI.—*continued.*

Name of company exploiting oil.	Production, 1901.		Production, 1902.	
	Total production.	Fountain oil.	Total production.	Fountain oil.
111. Russian Oil Co. (public company)	4,698,000		3,632,000	
112. Russian Oil Co.	221,000		228,000	
113. "Roos" Co.			172,000	
114. "Roos" (in Bibi-Eibat) Oil Co.	1,776,000		2,762,000	
115. Rilsky (1902, absorbed by Caspian and Black Sea Co.)	5,364,000	414,000	253,000	
116. Saboontchy Oil Co.	2,018,000			
117. "Saboontchy" Co.	1,660,000		1,114,000	
118. St. Petersburg Oil Co.	648,000		737,000	
119. "Sinai"	1,078,000		985,000	
120. Souchastniki	3,036,000		3,406,000	
121. Schibaieff Petroleum Co.	23,301,000	12,064,000	24,545,000	13,782,000
122. "Schikhoff" Co.	2,145,000		9,004,000	6,725,000
123. Schumacher, M. M.	957,000		610,000	
124. "Schooschin" Co.	746,000		776,000	
125. Shagidanoff and Co.	590,000		1,853,000	
126. Shirvan Co.	122,000		584,000	
127. Soombatoff	518,000		653,000	
128. Sunik	287,000		308,000	
129. Sarookhanoff	309,000			
130. Taroosoff			134,000	
131. Tairoff, E. A., and Co.	97,000			
132. "Tamara"	1,305,000		1,766,000	
133. "Taron" Co.	1,030,000	1,022,000	10,000	
134. Tiflis Co. (Bibi-Eibat)	5,010,000		2.129,000	
135. Tiflis Co.	826,000		1,002,000	
136. Ter-Akopoff Oil Co.	8,424,000	2,340.000	6,026.000	
137. Ter-Kasparoff, M. A.	271,000		123,000	
138. Tumaieff Bros.	4,186,000		4,797,000	
139. Tumaieff and Co.	16,701,000	220,000	14,406,000	559,000
140. United Russian Co.			69,000	
141. "Vanand" Co.	862,000		792,000	
142. "Vastak" Co.	1,627,000		1,455,000	
143. Vartanoff Bros.	1,353,000		1,082,000	
144. "Votan" Co.	408,000		1,301,000	
145. "Vorotan" Co.	1,554,000		529,000	
146. Vorotan and Ter-Markaroff	1,489,000		5,685,000	
147. Volga-Caspian Oil Co.	192,000		723,000	
148. Zatouroff, A.	1,754,000		1,584,000	
149. Zeinaloff and Akhundoff	407,000		427,000	
150. Zoobaloff	13,260,000		27,876,000	13,291,000
151. Zovianoff Bros.	1,363,000			
Grand total	671,276.000	98,119,000	636,040,000	94,780,000

It will be observed, on inspection of the list, that Nobels extract about 12 per cent. of the total quantity of oil from the Baku fields, whilst 50 per cent. is secured by ten of the leading companies.

The following is a list of the English companies in the Baku oil fields, with the situation of their properties:—

Name of company.	Situation of properties.
Baku-Russian Petroleum Co.	Balakhany, Saboontchy, Romany, Bibi-Eibat.
Balakhany Syndicate	Balakhany (Bog-boga).
Bibi-Eibat Petroleum Co.	Bibi-Eibat.
Eastern Oil Co.	Balakhany.
European Petroleum Co.	Balakhany, Saboontchy, Romany.
Kalantaroff Oil Co.	Saboontchy.
Romany Syndicate	Romany.
Russian Petroleum and Liquid Fuel Co.	Bibi-Eibat.
Russian United	Balakhany and Bibi-Eibat.
Schibaieff Petroleum Co.	Balakhany, Saboontchy, Romany, Bibi-Eibat.

The English companies have not generally proved a success, partly on account of over-capitalization, and partly through insufficient working capital being allowed, although the class of work has usually been better, and the output per well greater than Russian companies. Some of the above companies have already wound up or suspended work. The Balakhany Syndicate secured the lease of a plot on the side of Bog-boga, where, it is reported, £50,000 were spent in stores, machinery, and buildings before the land was tested, subsequent boring proving the ground to be only slightly petroliferous, and consequently valueless. The Government was petitioned to relieve the company of the plot, to which it ultimately agreed. The Bibi-Eibat Petroleum Co. was formed to purchase the lease of properties in Bibi-Eibat, secured from the Government at a royalty of about 7 copecks a pood, and as the price of oil fell nearly to this figure after the acquisition of the land, the enterprise has never obtained any profitable return.* The Eastern Oil Co. holds a very impoverished property in a region where only small productions can be obtained, and it is certain that it will never pay a fair return on the necessary expenditure required to raise the production, unless the price of oil exceeds 10 copeks per pood. The Kalantaroff Oil Co. secured a long lease of the 68 plot in Saboontchy, which was so badly mismanaged—four years' work on the plot failing to produce oil, although neighbouring properties were bailing as much as 5000 and 6000 poods a day from wells—that it was, in 1901, sub-leased to the Schibaieff Petroleum Co., after active neighbours had partially drained the area. The Romany Syndicate, which possesses one of the most promising new plots in the outlying districts of Romany, has suspended operations just when it was on the eve of success, for it penetrated oil ground, but failed to exclude the surface water. The great mistake here was the expenditure of a pile of money on houses, stores, boring tools, etc., when a contractor could have been engaged to drill the pioneer wells at a moderate rate, and no other expense need have been incurred. £12,000 would have paid all the expenses connected with the administration and boring of two test wells on the plot to a depth of about 1400 feet, and as, doubtless, a much less depth would have sufficed to obtain oil, £8000 to £10,000 would have covered everything (see "Contract Boring," Chapter V.).

The Russian United owns a valueless property in Balakhany, that will probably never repay any outlay, for numerous concerns all round have failed utterly in their endeavours to strike oil in payable quantities; the Bibi-Eibat property, leased from the Government at a royalty of only 1·782 copecks per pood, may turn out to be a valuable holding, although oil will be struck at a great depth, and the cost of boring will be excessive. The large companies hold in many cases very valuable lands, and their want of success is attributable to misfortunes that originated in their flotation, are exaggerated by over-capitalization, and intensified by the severe crisis through which the oil industry has passed. The Schibaieff Petroleum Co. that was formed on a very substantial basis, owns a number of very small-producing properties which can only repay exploitation when the price of oil is high. In 1901 and 1902 over 50 per cent. of the Schibaieff's production was obtained from two properties (No. 29, Bibi-Eibat and No. 102 Romany).

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* The Government has since re-leased the plots at a royalty of 27 per cent. of the production, but this decision has not yet been ratified by the Senate. If the land is obtained on these terms, the company should be on a fairly substantial footing when prices reach 10 copecks per pood.

In the year 1901 the English companies in Baku produced 108·9 million poods of oil, about 16 per cent. of the total production; and in 1902 they raised 91·9 million poods, about 14 per cent. of the whole output.

Division of Properties fn the Baku Oil Fields.—The oil properties of the Apsheron Peninsula are divided into seven classes, as follows:—

I. Properties which have been granted to private individuals by Imperial decree. All the plots composing this class lie in the well-drained Balakhany district, and in 1901 the 95 dessiatines (256·5 acres) constituting this group yielded only 37,400,000 poods of oil from 302 bailing wells, an average of 128,700 poods per well.

II. Government lands that have been leased by public auction on a royalty basis with a minimum annual payment to the Treasury. The 294 dessiatines (794 acres) comprising Class II. yielded, in 1901, 162,000,000 poods of oil from 260 wells, which makes an average of slightly over 623,000 poods per well per annum.

III. Government grounds leased on a royalty basis without public auction. The plots classified under this category are chiefly small pieces of land, which, in themselves, do not reach the regulation limit of size (1 dessiatine), and these are usually leased to proprietors of adjoining properties who petition the Government for permission to extend their lands. The total area of the twenty-five plots composing this class is only 22 dessiatines (59·4 acres), and the thirty-four wells yielded, in 1901, 22,000,000 poods of oil, or 646,000 poods per well.

IV. Government properties rented in accordance with a law issued February 1, 1872, which permitted certain lands to be leased at a rate of 10 roubles per dessiatine for a period of 24 years, after which the rent is increased to 100 roubles a dessiatine for a similar time. Twenty-three plots were so leased, having a total area of 193 dessiatines (521 acres), and in 1901, 108,000,000 poods of oil were extracted from 429 wells, an average of 252,000 poods per well.

V. Government lands rented by the villagers, who have to return them to the authorities after a fixed time. Included in this group are a few immensely valuable properties in the Bibi-Eibat oil field, the lease of which expired in 1901, but the Government, after due deliberation over the petitions of the lessees, decided to re-lease the plots to the existing proprietors at a royalty of 35 per cent. of the production. In 1901, 64 dessiatines, constituting this class, yielded 40,300,000 poods, secured from fifty-seven wells, which is nearly 708,000 poods per well.

VI. Freehold lands, to which private persons hold indisputable rights, and upon which the Government has no claim. Many stories are popularly related in Baku which describe how certain Tartar and Armenian millionaires became possessed of their lands in the Balakhany-Saboontchy-Romany oil fields by deliberately bribing the natives to swear to their ownership of certain lands, formerly valueless, when the oil craze developed. This class claims 240 dessiatines, and in 1901, 661 bailing wells yielded 186,000,000 poods of petroleum, or nearly 282,000 poods per well.

VII. Lands upon which permission has been granted to bore, but to which the Government disputes the rightful ownership. These territories lie exclusively in the Romany region, and amount to 59 dessiatines (159 acres), where, in 1901, 182 bore-holes yielded an output of 112,870,000 poods of oil, an average of close on 620,000 poods per well.

In Appendix A will be found a list, giving the number and designation of each property, the area in dessiatines and square sagenes, and the lessee's name for each plot under exploitation in the seven classes named above

In Appendix A are also given particulars of each separate property in Balakhany, Saboontchy, Romany, Zabrat, and Bibi-Eibat, since the year 1896. These tables give the number of productive wells; total production of oil; average production per well; average depth of wells; maximum and minimum depths of producing wells. Each plot will be found on reference to the map of the Baku oil fields, which accompanies this work.

Labour on the Baku Oil Fields.—In the year 1898 there were about 14,000 persons engaged in the exploitation of oil on the Baku oil fields; but in 1902 the number had increased to 24,000, from which figures some idea of the magnitude and increase in the oil industry may be gleaned. Compiled statistics show that true Russians only form about 25 per cent. of the employees on the oil fields, while Caucasians compose 43 per cent., and Persians of foreign extraction constitute 22 per cent., the actual numbers in April, 1902, being as follows:—

Russians		6,163	25·6 per cent.
Caucasian Tribes—			
1. Armenians	5088	10,387	43·3 ,,
2. Tartars	2383		
3. Lesghines	2687		
4. Grozines	143		
5. Osetines	85		
Other Russian Subjects—			
1. Tartars (Kazan)	1461	1,835	7·6 ,,
2. Jews	149		
3. Poles	108		
4. Other races	117		
Foreigners—			
1. Germans	232	5,633	23·5 ,,
2. English	13		
3. French	10		
4. Other European races	31		
5. Persians	5347		
		24,018	100·0

The 24,018 employees in the oil-extracting business are divided up as follows:—

Administration	452	1·9 per cent.
Offices	420	1·8 „
Workshops	5,542	23·0 „
Borking work	5,360	22·3 „
Property work	10,495	43·2 „
Other occupations	1,749	7·3 „

The large number of races employed on the oil properties very considerably complicates the work of management, for a large percentage of the Armenians, Tartars, Persians, and other nationalities do not speak Russian; and unless the manager is acquainted with these chief languages, and has a knowledge of a few Caucasian dialects, the use of interpreters is unavoidable. The mechanics employed in the workshops are chiefly Russian and Armenian, but more than 50 per cent. of the Germans are also of the skilled artisan type. The daily work on the properties, such as cleaning the settling tubs, chutes, etc., is done by Persians; but the bailing is conducted more by Tartars, the peasant type of Armenians and Lesghines, the latter, owing to their fearless nature, also making excellent watchmen for the properties. Most of the labourers are drawn from the village peasant class, who flock towards the oil fields in the winter months, when there is little occupation on the farms, and who leave their situations to return to the country for the hay-making and harvest in the summer, causing a dearth of labour each summer.

The employment of so many races in the exploitation of oil, causes much disarrangement of the work at holiday-times; for, the Russians, Armenians, and Tartars all claim their special holidays for religious festivals, which fall at different times in the year, and lead to disturbances unless previously arranged for. The difficulty has been met in Baku by the nomination by the Russian authorities of certain dates when employers are compelled to release their men, or pay them a fixed extra pay, both the days and the wages in lieu of holiday being printed in each workman's book, without which latter no engagement is legal.

The Grosny Oil Field.—The Grosny oil field lies on a range of hills situated about 8 miles to the north-west of the town of Grosny, to which town it is only connected by a rough trodden track that traverses the level valley flanging the range. The anticline coincides approximately with the formation of the hills, which extend in a direction from north-west to south-east, but the oil strata are not found at an equal depth, even when due allowance is made for the differences of level. About the neighbourhood of the Mamakai region, the petroliferous formations reach the surface; indeed, for nearly 20 years petroleum has been extracted from hand-dug wells located near this district, but in both directions from this point the productive beds become deeper, the actual degree of which, for limited distances, is fairly well known. It is, however, possible that the strata may again approach the surface at further removed spots, although such a view is not encouraged by the surface appearances. The accompanying map, which is a reduced copy of the Russian official plan of the Grosny district, shows the extent of the oil fields, and its value is increased by the insertion of contour lines that permit one to trace the hills and valleys. A section of the strata taken at right angles to the range of hills would, doubtless, exhibit different features at various positions, but in all cases the slope of the anticline on the north side is exceedingly steep, whilst that on the south side is gentle. In some localities on the northern side deep borings situated within a short distance of producing wells have failed to penetrate petroliferous strata, and have been abandoned at great depths—a result which leads one to suspect the existence of a fault of which there are no surface indications. Some Grosny authorities discard the fault theory in favour of the view that the beds are folded in a complex manner on the northern side; but extended and systematic trials can alone prove which geological conditions actually exist. It is worthy of note that oil indications occur on the Terek range of hills which rise from the opposite side of the plain, and run parallel with the Grosny range. The sketch gives the probable arrangement of the strata that would be exposed in a transverse section of the range near the Mamakai region.

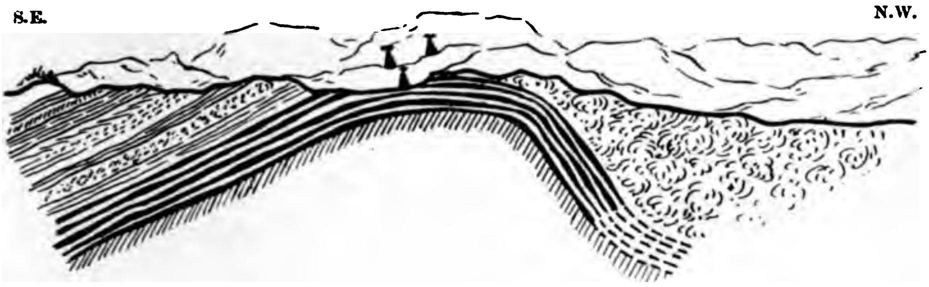

Fig. 24.—Rough Sectional Sketch of Possible Position of Strata in Parts of the Grosny Range.
(Black lines indicate oil-bearing beds.)

The nearest exploited plots are reached about 7 miles from Grosny, on the summit and sides of a steep hill, and from thence the explored ground lies in an almost straight line over hills and valleys for a distance of another 7 miles. One or two trial wells are in course of boring even further out than this, which will, on completion, furnish valuable information concerning the continuation of the Grosny oil beds. On account of the sharp dip on the northern side, in addition to the presence of an immense accumulation of alluvial matter, and thick deposits of sedimentary beds on the southern side, the oil-bearing strata only lie at a depth which allows profitable drilling over a width of less than half a mile, so that the field can only extend laterally when the price of oil will repay deep boring, or when cheap methods of drilling are introduced.

The strata of the Grosny oil field are very unlike those of the Baku regions, for not only are the deposits highly impregnated with lime, which imparts to them a marly character, but the well-defined, highly petroliferous, loose sands, so prevalent at Baku, are quite absent, and in their place are found sandy strata which, when washed, display little indications of oil. When the upper water is shut off, the presence of oil ground is usually shown by the accumulation of oil in the bore-hole, and the displacement of the little water which is always present, and which, indeed, is necessary to conduct the boring; but in any case, there are well-defined zones, as in Baku, where the engineer naturally uses more than usual care in his inspections. Five distinct oil horizons have been traced wherever boring has been conducted deep enough, but there are almost sure to be others, as there are no signs in the lowest beds to lead one to conclude that the bottom of the series has been reached.

The Grosny oil strata are not nearly so prolific as those of Baku, for the wells dry up, as a rule, after a brief period of spouting or fair bailing. The first two bored wells were completed in 1893, and the results were so promising that, for a time, the district was generally considered to be a serious rival to Baku, but subsequent exploitation, although occasionally disclosing large producers, has proved somewhat disappointing. The wells are not located near together, as around Baku; the properties, for the most part, are not surrounded by neighbours who are inspired with a spirit of rivalry; the slopes of the anticlines are not generally exploited where they might seriously menace the richness of the apex of the range, along which are congregated most of the oil properties; nevertheless, the total production from a single well is small, and its life is usually short. The first bored well is reported to have yielded as much as 800,000 poods a day for a few days, and recently a well completed by the Kasbek Syndicate flowed, it is said, at a rate of nearly 2,000,000 poods a day, much of which was water; but its life was exceedingly short, and scarcely repaid the expense it incurred. Table XII. gives the productions of the chief Grosny firms and the number of wells, from which it will be seen that the average production per well, for the three years 1899, 1900, and 1901, was 475,000, 370,000, and 406,000 poods respectively.

TABLE XII.

GROSNY STATISTICS FOR 1899, 1900, 1901.

Property.	Total production.			Number of wells.			Average production per well per annum.		
	1899.	1900.	1901.	1899.	1900.	1901.	1899.	1900.	1901.
Ackverdoff. (Emoloff, without No.)	4,261,400	2,075,600	1,949,900	13	11	7	320,108	188,691	278,557
Ackverdoff. (No. 977.)	9,244.600	6.694.300	5,419,700	8	9	10	1,115.575	743,811	541,970
Ackverdoff. (No. 22.)	138,500	298,200	116,400	2	2	1	69,250	149,100	116,400
Ackverdoff. (No. 23.)	537,400	1,616,800	2,572,600	2	5	5	268,700	323,360	514,520
Ackverdoff. (No. 24.)	51,000	59,900	1,753,200	1	1	4	51,000	59,900	438,300
Ackverdoff. (No. 975.)	6,039.600	4,376,900	2,262,900	5	10	8	1,207,920	437,690	282,863
Anglo-Russian Maximoff. (Emol., no No.)	1,870.320	3.495.290	5,799,150	9	11	9	207,813	317,754	644,350
Moscow Co. (Grosny, no No.)	1.862.645	1,210,501	481,700	7	9	3	266,092	134,500	160,567
St. Petersburg Oil Co. (No. 976.)	1.026.581	1,056.924	490,260	4	6	5	256,645	176,154	98,052
Russian Standard. (No. 10.)	230,520	1,657.815	2.024,495	1	6	6	230,520	276,303	337,716
Spies Petroleum Co. (No. 15.)	32.000	2.441,000	6,557,494	1	7	13	32,000	348,728	504,423
Spies Petroleum Co. (No. 16.)		5,472,000	4,076,683		4	11		1,368,000	370,608
Spies Petroleum Co. (No. 32.)		232.150	467,036		2	2		116,075	383,518
Spies, Stucken & Co. (No. 12.)			215,586			1			215,586
	25,195,666	30,678,480	34,487,104	53	83	85	475,389	369,734	405,731

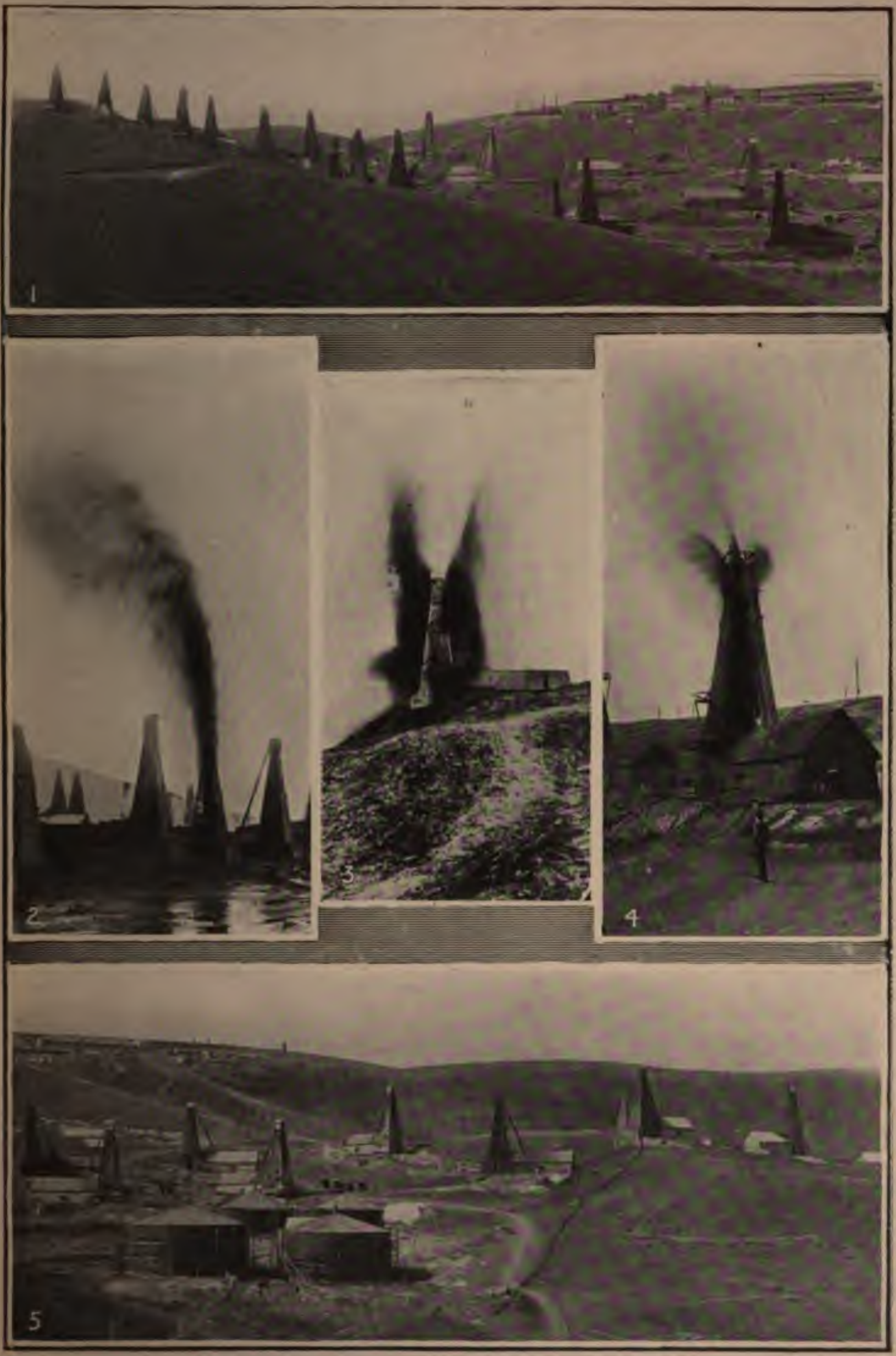

Fig. 25.—Some Views of the Grosny Oil Field.

1. Plots Nos. 15 and 16 of the Spies Petroleum Co., Ltd.
2. View of Anglo-Maximoff plot, showing Well No. 21 spouting.
3. One of the largest Grosny fountains on Ackverdoff's plot.
4. Well No. 38, on Ackverdoff's property, spouting.
5. View of Spies Petroleum Co.'s plots 5 and 16. (Characteristic of Grosny.)

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EXTRA TO TABLE XII.

Property.	Total production.			Number of wells.			Average production per well per annum.		
	1902.	1903.	1904.	1902.	1903.	1904.	1902.	1903.	1904.
Ackverdoff. (Emoloff, no No.)	11,258,300			8			1,407,287		
Ackverdoff. (No. 977.)	2,244,100			10			224,410		
Ackverdoff. (No. 22.)	133,500			1			133,500		
Ackverdoff. (No. 23.)	703,400			5			140,680		
Ackverdoff. (No. 24.)	438,600			4			109,650		
Ackverdoff. (No. 975.)	1,439,600			12			119,966		
Anglo-Russian Maximoff. (Emol.,no No)	5,053,703			10			505,370		
Moscow Co. (Grosny, no No.)	778,230			7			111,176		
St. Petersburg Oil Co. (No. 976.)	776,880			6			129,480		
Russian Standard. (No. 10.)	1.254,360			9			139,374		
Spies Petroleum Co. (No. 15.)	3,885,230			16			242,827		
Spies Petroleum Co. (No. 16.)	1,391,113			12			199,326		
Spies Petroleum Co. (No. 32.)	544,954			2			272,477		
Kasbek Syndicate. (No. 12.)	1,882,244			1			1,882,244		
Cheleken-Dagent Co. (No. 11a.)	738,333			2			369,166		
Cheleken-Dagent Co. (No. 11b.)	149,551			1			149,551		

The results in 1901 were at a time when there were only 85 bailing wells spread over an area of many square miles, and this compares very badly with Bibi-Eibat, which in 1900 had 112 producing wells, averaging 975,000 poods per well; Romany, in 1896, with 84 bailing wells, averaging 929,600 poods; Saboontchy, in 1892, with 230 wells, averaging 673,000 poods; and the old Balakhany field, which in 1892 gave an average of 340,000 poods per well per annum from 169 wells, although the district had been actually drilled upon for 20 years.

There were two English firms producing oil in Grosny in 1901, who collectively extracted 17·4 million poods of oil, nearly 50 per cent. of the total output from the Grosny field.

Below will be found the total yearly production of Grosny since 1896, in poods—

1896.	**17,200,151**	1901.	34,652,271
1897.	**27,568,794**	1902.	34,072,271
1898.	**17,716,899**	1903.	
1899.	**25,194,566**	1904.	
1900.	**30,687,948**	1905.	

In 1901, the average depth of bailing wells was 134·3 sagenes, and fountain-wells 181 sagenes. The depths vary from 54 sagenes to 233·9 sagenes.

Fig. 26 is a plan of the Grosny district, showing the town of Grosny on the right and the oil-producing range of hills running south-east to north-west. The contour-lines enable an accurate idea of the character of the region to be obtained. In Appendix A will be found the particulars of each Grosny property separately.

The Chatma Oil Field.—Recently, attention has been attracted to a district known by the name of Chatma, lying about 50 miles from Tiflis, in the government of Tiflis, where indications of oil are sufficiently prevalent, in the opinion of some people, to warrant exploitation work. The nearest station is Poili, situated on the Trans-Caucasian Railway, about 300 miles from Baku and 260 miles from Batoum, a station which is only connected with Chatma by a miserable track some 18 to 20 miles long. The oil field is approached by making a steep ascent from the railway and then following a series of plains shielded by high bare mountains; but the soft calcareous ground is so cut up with ravines, which traverse the plain in all directions, that great delay is occasioned by fruitless journeys unless the regular track is severely followed. The Chatma plateau is an almost level plain (also cut up considerably by gorges excavated in the soft strata by streams of water which rush down from a large drainage area in wet weather), about 8 miles long by 3 miles wide, flanked nearly all round by precipitous cliffs which impart to the region a most imposing appearance. The elevated plain is the result of a considerable terrestrial upheaval; for the strata have been forced into a vertical position, and, on the flanks of the valley, disintegration has been in force, and caused the harder beds composing the hills to stand out well-defined from the general formation.

Indications of oil are common along the cliffs, and not only are beds of hard, compact, black bitumen, which the local peasants call coal, discernible, but there are deposits of highly discoloured oil sands, from which a little heavy oil exudes, and thick deposits of kir at the base of the cliffs, which can only have originated from effusions of oil. In some places tiny evolutions of oil and water may be traced oozing from the cliffs, which flow into shallow trenches excavated by the natives for its reception, from whence the floating oil is periodically skimmed for employment in household operations. At the base of the cliffs at the west of the valley the outcrop of an oil sand may be traced for a long distance along the ground, and into this a number of wells have been bored, by primitive hand-boring appliances, to a depth of 50–150 feet, which have yielded small quantities of black petroleum of a specific gravity exceeding 0·920. An ordinary bucket is lowered into the well by means of a windlass placed over the well, and a single Tartar attendant operates several wells, which only slowly fill after being emptied. The strata cannot be so readily traced in the centre of the plain on account of the disturbed condition of the surface-material, although where traces are visible the same acute angle is observable; but as there are a number of mud volcanoes which constantly eject mud and water contaminated with oil, one may fairly assume that the oil-bearing beds continue across the plateau. The verticality of the strata, exposing a broken

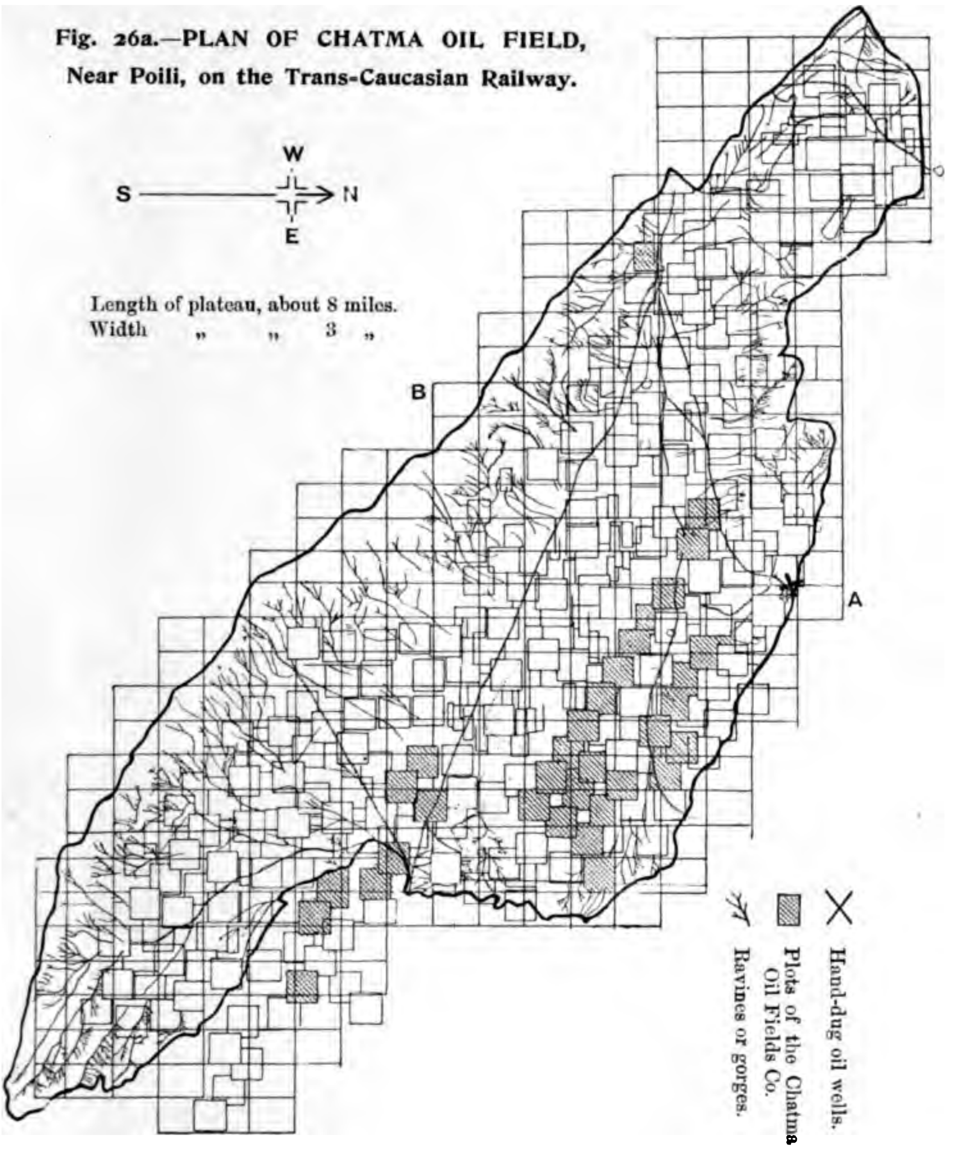
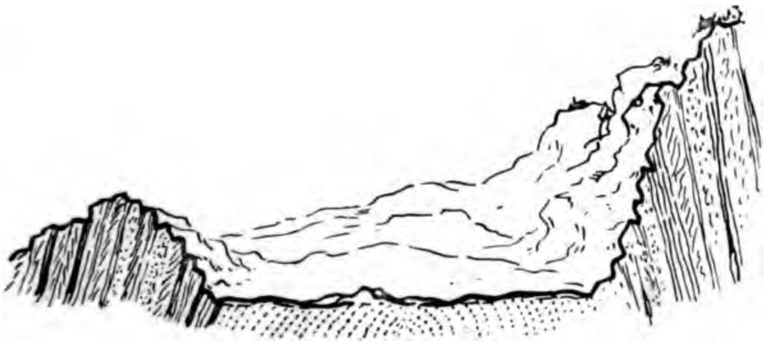


Fig. 26a.—PLAN OF CHATMA OIL FIELD, Near Poili, on the Trans-Caucasian Railway.

Length of plateau, about 8 miles.
Width " " 3 "



Rough Sectional Sketch across Plateau near Points marked A B.

(**Black bands** represent beds of oil sands and layers of bitumen.)

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TILDEN FOUNDATIONS

edge to the surface of the ground, naturally permits all the oil-bearing beds to expel their contents, so that little can be expected from such oil strata unless penetrated to a great depth. Boring is not conducted without serious risk on such inclined strata, for it is obvious that if the angle of the beds is 15°–20° out of vertical, the depth of boring needed to perforate a single layer 20 feet thick is 20 cosec 15° = 77·2 feet, or 20 cosec 20° = 58·4 feet, thus necessitating three to four times the amount of boring to reach a certain source than on horizontally disposed formations.

The most likely spot to secure a fair production would be near the apex of the anticline, or, in the event of there being two or more—a not impossible circumstance—the apices of these, so that unbroken and unexposed strata may be tapped.

The Binagadi Oil Field.—For several years exploitation has been conducted in a district to the west of Balakhany near to the village of Binagadi. The region has long been known to be oil-bearing, but no active exploration was commenced until an oil prospector sank a well, and struck an oil source in 1896. Since that date other wells have been bored around the original site, and further interest has been attracted to the place by the appearance of a small fountain, in 1901, which yielded about 100,000 poods of petroleum. The oil is very heavy, exceeding, generally, 0·900 sp. gr., and the wells rapidly dry up when bailed.

The strata of the district are similar to those of Balakhany, consisting of calcareous clays, sandstones, and petroliferous sands; but the strata outcrop at the surface at an acute angle, and permit the escape of gas from the strata that might otherwise be employed in expelling the oil. The prospects of obtaining oil in payable quantities, at a reasonable depth, are remote, although deep boring might disclose the existence of prolific sands where they are uninfluenced by the surface exposures.

Statistics confirm the impression usually created by such a geological condition, and prove the unpayable character of the shallow beds, at least. Table XIII. gives the particulars of Binagadi wells for the last few years.

TABLE XIII.

GIVING NUMBER OF WELLS, AVERAGE DEPTH, TOTAL PRODUCTION, AND AVERAGE PRODUCTION PER WELL PER ANNUM FOR BINAGADI.

Year.	Number of wells.	Average depths in sagenes.	Total production in poods.	Average production per well.
1896	1		28,816	28,816
1897	3		197,462	65,821
1898	4	51·95	227,730	56,932
1899	8	60·06	213,386	26,673
1900	12	62·00	406,517	33,876
1901	13	65·70	468,118	36,009
1902	15	74·40	488,423	32,560
1903				
1904				
1905				

The situation of the Binagadi district is not unfavourable, lying as it does only about 7 miles from the Blacktown refineries and the sea-shore, whilst the railway junction of Baladjari is not more than 2 miles from the oil properties.

The Puta Oil District.—A well-defined anticline sweeps all round Baku, the apex of which coincides with the base of a valley that follows the coast-line for many miles after approaching the western side of the Bibi-Eibat field. Puta railway station lies about 8 miles south-west of Baku, but the distance by railway is about 20 miles, owing to the fact that the Trans-Caucasian Railway keeps to the valleys in order to escape the limestone range that divides Baku from the hinterland. The plain is perfectly devoid of vegetation, as a result of the escape of sulphurous and other gases as well as salt water. In winter, many miles are rendered quite impassable by accumulations of water, and in summer the heat and glare rival many parts of the Sahara. The district has attracted more than superficial attention through its proximity to Baku, and as a result of the many indications of oil that are everywhere apparent in some form or other.

The beds forming the anticline have been forced into an almost vertical position, consequently exposing the fractured edges of the strata on the surface of the plain, and in consequence formations of divers characters may be recognized for long distances. Hills of asphalt have been formed in some places above the vertical petroleum beds, whilst in other cases exudations of gas only occur.

As far back as 1897, the Messrs. Nobel sank a boring near the outcrop of one of the beds, and at a depth of a few hundred feet a little flow of heavy oil was struck, and the well till this day discharges continuously a small quantity of thick black oil, resembling tar in consistency and appearance. The Government will not issue the necessary permission to bore on this district yet, their intention being, it is said, to hold this land in reserve—a decision the wisdom of which is doubtful, for the acute angle of the strata is not a favourable sign, and unless exploration brings to light the presence of strata lying in a more horizontal position, the value of this much-appreciated area is questionable.

Oil Fields of Small Extent: Khiddirzindi.—Amongst other oil regions tested in the Baku district is Khiddirzindi, a district that lies on the Baku-Petrovsk Railway line, close to the shores of the Caspian Sea. The numerous indications of petroleum led several syndicates to expend large sums of money in testing the quality of the ground, including two English companies, one of which, the Schibaieff Petroleum Co., spared no money in thoroughly exploiting a large piece of land held by them in the region. Oil sources were penetrated and trials were made of an extended character, and although one or two violent discharges of gas mingled with oil, sand, and stones occurred, which encouraged further investigations, the tests had to be ultimately abandoned on account of the unprolific nature of the petroliferous beds. The unsuccessful issue of the Khiddirzindi drilling operations has undoubtedly condemned the territory, and for many years to come interested investors will not risk a repetition of the experiment already made.

Khordalan.—Khordalan is a small Tartar village lying about 4 miles south-west of Binagadi and 7 miles north-west of Baku. Indications of oil are prevalent everywhere in the vicinity, and the railway, which passes close to the village, has been excavated in the side of a hill where an excellent section of the strata is exposed to full view. The cutting actually passes through strata wherein oil beds are interposed, from which a gentle stream of heavy oil constantly oozes and collects in trenches provided for its reception at the base of the bank. The nature of the soil is evidently more conducive to the growth of vegetation, for a coarse grass coats the earth and a little agriculture is permissible,—a result that rather perplexed the author, who eventually found this to be due to the presence of a horizontal series of beds above the main formations, which latter are to be seen reaching the surface at an angle in the valleys, where water has cut a channel deep enough to expose the lower series. An excellent section of the strata of the Khordalan district is illustrated in Figs. 13 and 14. The Russian Petroleum and Liquid Fuel Co., who have been boring a well on a plot (No. xxviii.) to the south of a hill near the village of Khordalan, in the spring of 1903, met with a strong fountain which threw up a large quantity of sand and oil at a moment when the tools were at work in the well, thus causing their loss and leading to delay in the exploration. The results, to some degree satisfactory, do not yet justify the drawing of any conclusion, and fuller investigations must be conducted to discover the practical worth of the field.

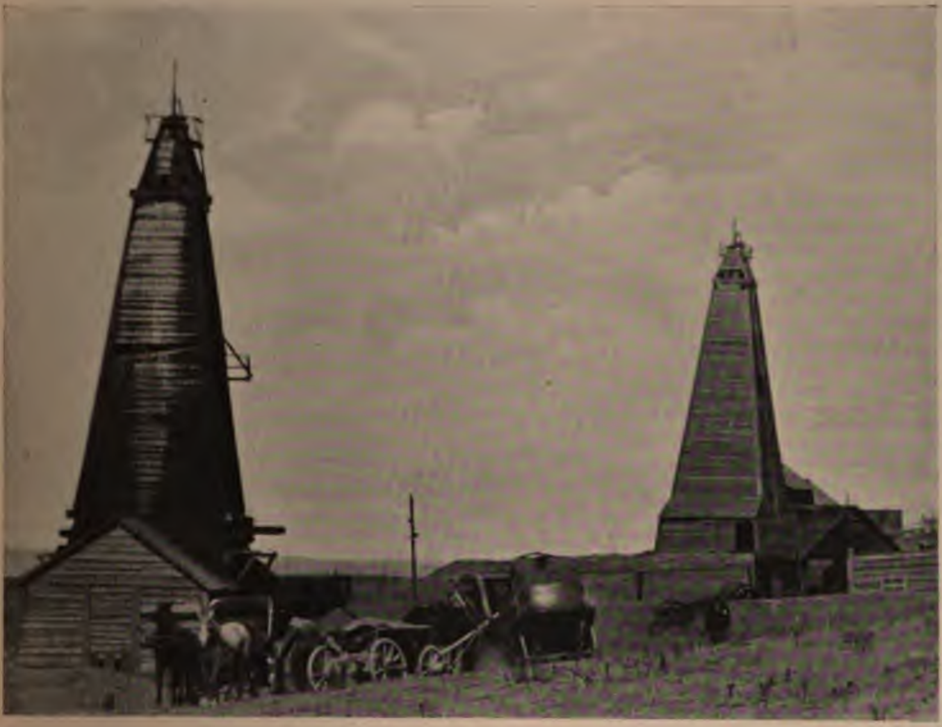

Fig. 27.—Khordalan District.

(Showing two wells being bored by the Russian Petroleum and Liquid Fuel Co.)

Digya, Sarai, etc.—A large area to the north, east, and west of Binagadi is known to be oil-bearing from the frequency of such phenomena as exudations of gas, oil, and salt water, escapes of sulphurous gases, and prevalence of mud volcanoes. Digya, Sarai, and other villages have transmitted their names to districts which surround them, where large areas are laid out and held under lease by many of the Baku companies and by private individuals.

Berekei.—The Berekei district, which has lately come into such prominence through the striking of a fountain by Nobels (November 29, 1902), that has yielded a steady production by flowing unassisted for many months, is located near the shores of the Caspian Sea, 17 miles from Derbent.

The stratum through which the oil is disseminated is evidently of a compact texture, for plugs have not been formed as a result of the spouting, such as would with certainty have occurred under similar circumstances in Baku. The value of the Berekei field must not, however, be decided by the result of a single well, although for a first trial the pioneers were exceedingly fortunate, for, after all, to strike the *first* oil stratum of a productive quality at a depth of 1400 feet proves the necessity for deep drilling, in the vicinity of this boring at least, and consequently of expensive exploitation. Messrs. Nobel Bros. are so far satisfied by the results that, it is reported, they are taking measures for more extensive work, and for the disposal of the petroleum, about a million poods having already collected in the reservoirs around the existing well.

As far back as 1893, a trial boring was carried to a depth of about 50 or 60 sagenes, which passed through several petroliferous bands, all of which proved to to be of no value when trial-bailed. Nobels put a little more spirit into their undertaking, and did not cease boring until, at a depth of 191 sagenes, a flow of oil (sp. gr. 0·868), checked further progress. Nobels' well is 12 inches in diameter, and it flows every 40–50 minutes for about 10–12 minutes, yielding during that period from 150 to 200 poods of petroleum. The ground penetrated by this well consisted of clays, oil clays, hard dark sands, sandstones, and marls or calcareous sands, from some of which as much as 100 to 200 poods of oil per day could be bailed, but the present oil apparently exudes from a dark calcareous clay, doubtless perforated by beds of sand. A 4-inch pipe has already been laid to the railway from the properties, and one or two other wells are being sunk by Nobels, as well as by other people. The anticline is said to run from north-east to south-west, but little can be judged of the geological conditions by a superficial inspection, and test borings will alone disclose the lie of the beds and the value of the petroliferous formations.

The position of Berekei from a commercial point of view is far from unsatisfactory, being in communication with the main railway line, and having the sea within a short distance, which is useful both for transport facilities and the supply of water for commercial purposes if ordinary supplies fail. Rains, however, are much more common in this neighbourhood than in the Apsheron Peninsula; vegetation flourishes as a result, and provides produce and pleasures of which Baku cannot boast. Unfortunately, mosquitoes are, it is reported, a veritable pest in the summer months, and render the evenings almost unbearable; and malarial fever cannot be avoided if a lengthy residence is made on any of the damp, hot plains flanking the Caucasus.

Tcheleken Island.—The island of Tcheleken really represents the first exposed portion of the range of submerged hills which crosses the Caspian from the extremity of the Apsheron to the Trans-Caspian provinces, at which latter place they exhibit the same petroliferous character as in the Caucasian districts. Tcheleken has for centuries been known to yield oil, and, indeed, the island has been described by some travellers as a sodden mass of asphalt and the non-volatile products of petroleum. For many years exploring work of a desultory nature has been going on, which has only served to prove the existence of oil, the depths of the wells being insufficient and the manner of exploitation too rude to deduce any valuable conclusions. Mud volcanoes are plentifully distributed over the island; oil and gas freely escape from the earth; and hand-dug pits, even a few feet deep, yield a production of dark-brown oil that will scarcely flow.

The formations on Tcheleken Island arouse more than usual interest from the fact that, whereas most Caucasian oils are remarkably free from paraffins, the petroleum here is comparatively rich in these hydrocarbons, causing them to fill a place in the Russian oils hitherto unoccupied. From some wells a thick pasty mass of almost solid matter can be freely extracted, having a dark-brown colour quite different from any of the Caucasian heavy oils or kir deposits. The consistency of this semi-solid petroleum—for it can be handled freely in blocks—prevents it, of course, from being bailed, and it can only be raised from bore-holes by augers, or collected by excavating a large pit until the bed is reached.

The existing wells on the island, which have been drilled by antiquated hand-boring plants, do not exceed 500 feet, but nevertheless small fountains of oil mixed with water have been struck, from which a daily production of 500 poods could be raised. Two wells, in 1901, gave as much as 150,000 poods, although only 400 and 500 feet deep respectively, whilst the total output from the island in the same year is stated to be 600,000 poods. It is understood that Nobels are soon likely to make a large practical use of the paraffin-containing oils of Tcheleken, when large developments may be expected on the island.

Holy Island.—Holy Island is a long narrow strip of land which has an area of about 3½ square miles, protruding from the Caspian Sea, 3 miles from the north-east coast of the Apsheron Peninsula, and about 50 miles from Baku by sea. The island has resulted from an upheaval which has thrust upwards a ridge, thus producing an anticline that runs from north-west to south-east, exposing a strip of petroliferous strata flanked on both sides by the same local limestone series that overlie the Apsheron oil-bearing formations. The petroleum of this island was known to the ancients, and doubtless the isle derived its name from some connection with fire-worship, whilst at a later period the Persians extracted large quantities of oil from accumulations in the vicinity of natural exudations.

All the common phenomena which attend the petroleum deposits, where located near the surface, are to be found on Holy Island, and for a number of years Messrs. Nobels have been conducting exploration work, with a view of testing its practical value. Small fountains have occurred, and some petroleum has been extracted, but, so far as is known, no valuable sources have been penetrated that would warrant extensive operations.

Other Oil Districts.—Oil ground has been tested in many other parts of South-East Russia besides those mentioned, but never, as yet, with very successful results. There is oil in the Gouria district near Batoum; on the Mogan Steppes and Trans-Caspian provinces oil indications are frequent; whilst petroleum signs pervade huge districts to the south of the Caucasian range. Kara-Su is a region exhibiting petroleum phenomena on an extensive scale, but the locality has never been worked. The Crimea, the Taman Peninsula, and many spots on the north of the Caucasian Mountains have for years been worked for oil; and in the Kaikend district the Anglo-Russian Oil Co. have been exploring a huge tract of country for some years without much reward, although oil in small quantities has been obtained. Many patches of land in the Petrovsk and Derbent regions can also boast of petroleum traces.

CHAPTER V.

BORING.

Boring.—Method in Russia still fundamentally the old free-fall system—Causes of failure of belauded American drillers—Crude machines used partly due to labourers and local conditions—Reasons alleged for failure of new systems—Method of raising oil responsible for large diameter of wells in Russia—Relation of diameter of upper and lower tubes in a well—Probable future modification of boring due to compressed air method of raising oil.

Surface Shaft.—Practical reasons for this preliminary.

Derrick.—Object of erection—Ordinary construction—American construction now frequently used—Description.

Boring Machines or Frames.—Description of common Russian boring rig.

Systems of Boring.—Classification of systems in use in Russia—Russian free-fall system, details, and conditions of progress—Material used for rods—American rope system—Early failures in Russia due to local geological conditions—Modifications rendering method successful—Biering's patent—Advantage of rope method—Requirements for success—System on the whole less suitable for local strata—Tools required and method of use—Wire-rope system—Lentz's system only one used in Russia for many years—Advantages and description—Successful conversion of American rope system into wire-rope system—Drawbacks—Canadian pole tool system—Practical identity with American rope rig—Objections to its adoption—Advantages claimed—Galician system—Modification of Canadian arrangement—No great success attained in Baku district—Mather and Platt borer—Details of tools and method of use—Reasons why unsuccessful in Baku district—Diamond drill—Tried and proved to be unsuitable for Baku strata—Calyx drill, a late introduction from Australia—A modified diamond drill—Description—In common with other water-flush systems, unsuited for wells of large diameter—Difficulties in Baku district owing to loss of water in sand strata, and interference of water with neighbouring wells—Poor results in passing hard sandstones—Risk to tools in case of a sudden fountain or instantaneous rising of huge sand plug—Chapman's Spindle-Top rig—Successful in Texas in passing great depths of quicksands—Possesses usual defects of water-flush systems—Description—A modification which might be successful at Grosny.

Trueing the Well.—Importance of first column of lining tubes—Device to secure verticality—Procedure in case of want of verticality.

Cleaning the Débris from Wells.—Description and use of sand pump—The "American pump or bucket"—Augers.

Fishing for Lost Tools, etc.—Occasional loss unavoidable—Skill and patience required in recovery—Procedure on breaking rods during boring, and in complicated case of breakage when tools have fallen some distance—Ascertaining minutely position of lost tools, etc., by impression block—Description of slip socket—Measures adopted when sand, etc., completely covers lost tools—Cutting up or driving away a tool in case of complete failure to lift—Ease of driving away massive tools in certain cases—Mr. Loran's stereo-photographic apparatus for obtaining views of lost or broken instruments—Every case of loss or breakage to be treated according to its own peculiarity.

Lining the Well.—Nature of Baku strata not allowing many feet of unprotected bore-hole—Troubles occasioned in old districts through loosening of ground by previous borings—Tubes sometimes stopping on porous ground being met with, and liquid in well suddenly disappearing—Impracticability of carrying one string of casing to great depths—Discretion required in use of driving monkey.

Repairing Wells.—Boring through collapsed and damaged tubes—Method of cutting up casing—Legal difficulties in the use of explosives.

Contract Boring.—Universal in America—Only partially employed in Russia—Contractors' methods—Advantages of employing contractors, in real cost, in speed of work, completion according to prearranged conditions—Terms of a Baku boring contractor, the part undertaken by company and the part by contractor—Details of cost of contract work.

CHAPTER V.

BORING.

Boring.—Notwithstanding the numerous systems of boring introduced into the Russian oil fields, and the innumerable arrangements patented, the old free-fall system continues to be the most favoured, and holds its own against all new methods. Modified, improved, developed, as it undoubtedly is, the underlying principle still remains, from which there has been little change, and from which there is little likelihood of immediate alteration. Many other methods are daily practised in the Russian fields which meet with more or less success, but nothing has yet been worked in the Baku district which has produced any startling improvements in the speed of boring, whilst many methods have been condemned as useless after only a few months' trial. Many systems are more or less an adaptation of the free-fall, and others work in conjunction with it. Most of the Baku systems, that are named after the contractor or person who introduced some special features, are solely the free-fall method with a differently arranged geared frame to transmit the sundry motions required.

American drillers, furnished with the highest references and testimonials, have been frequently engaged, and supplied with the best tools and machinery obtainable, with promise of rich reward if successful; but all of no avail—complete failure in every instance resulting. Representatives of almost every well-known drill or boring machine have in turn prophesied a revolution in boring on the arrival of their specialty; but few drills have been able to approach in utility, much less surpass, the old Russian system. Roughly made, badly fitted, and carelessly kept, are terms which moderately express the qualities of all but a few well-boring machines in the Baku oil regions, and they perform their work in that slow, sleepy mannner so characteristic of the native Asiatic employees who generally operate them. The existing boring machines and instruments are the results of a gradual development of a principle that suited the local requirement and to which the native labourer has adapted himself.

The usual excuses heard from the exponents of new systems, to account for their failures are: Impossibility of securing skilled and intelligent labour; strong prejudice against new introductions; and hostility to foreigners, who are generally the pioneers;—all of which are partly true, but not entirely, and, perhaps, the chief reason is because new-comers have not carefully studied the peculiar local conditions, and modified their machines to stand the special work. Too many boring processes, which, ill adapted in their original form, have been heralded in an imposing manner by interested persons, might, if completely rearranged and cautiously introduced into the district, give very good results.

The method of raising oil from wells by bailing is responsible for the large diameter of Russian bore-holes, which must be commenced very large to ensure oil being reached with a diameter from which bailing may be profitably conducted. The large diameter of borings is partly responsible for the failure of many of the boring systems introduced, which had previously never been tested for wells over 12 or 14 inches in diameter, and were quite out of proportion for such sizes as are commonly needed.

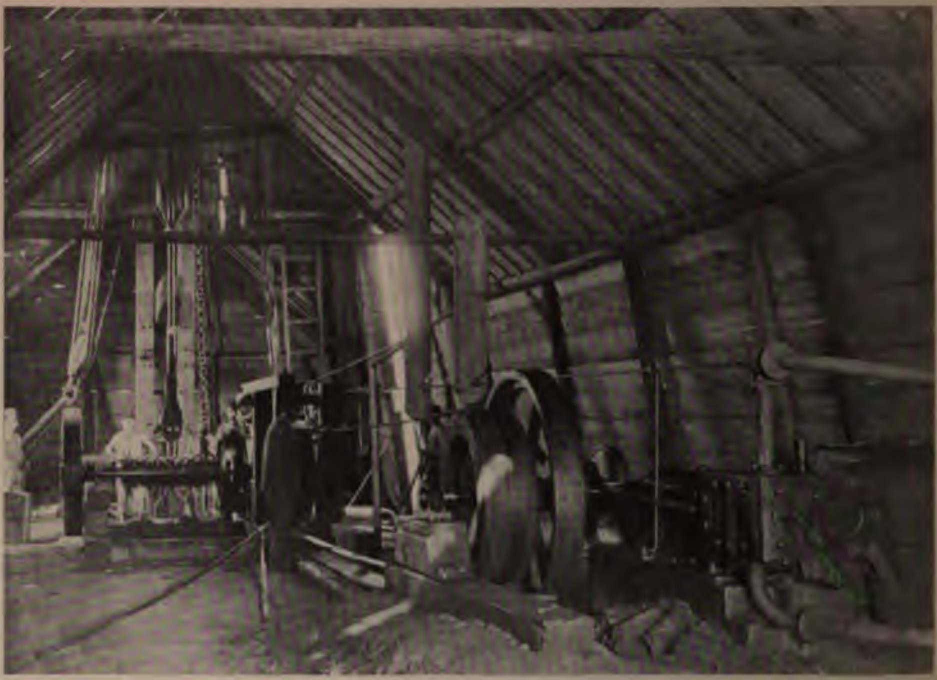

Fig. 28.—Interior of a Baku Derrick during Boring.

(Old type of boring machine, with separate walking beam.)

Experience has shown that if a well is to be completed at a depth of 1400 feet with a 14-inch or 16-inch tube, it is necessary to commence with a 26-inch or 28-inch casing; for the average distance each string of casing will sink with freedom is often not more than 210 feet in the Baku fields. There are examples of lining tubes passing freely 500–600 feet, but there are numberless instances where several strings of tubes in succession have only passed a few feet, and it is advisable never to rely upon too good fortune in boring, for no one can tell what accidents and unforeseen difficulties may crop up, which entirely upset the original calculations. The larger the diameter of the well on completion, the easier are the facilities for deepening when a source is drained, and one must admit that it is better to have a well of too large a diameter for the needs of bailing than one too small, which can neither be properly bailed nor easily deepened.

The introduction of compressed air, especially into high-level districts like Bibi-Eibat, may considerably modify boring during the next few years, as a well of small diameter is as suitable for this method of raising oil as a large one, and this innovation may lead to the initiation of more rapid and cheaper ways of sinking small holes.

Surface Shaft.—Before the derrick is erected, a pit is excavated to a depth of about 20 feet, and lined with a wooden drum about 12 feet in diameter, stayed with wooden ribs or angle-iron rings. The shaft is never omitted as a preliminary, and by its means the boring master is enabled to assure the absolute verticality of the first length of casing, upon the accuracy of which depends the remainder of the boring. Some boring masters prefer to conduct part of their work in the shaft instead of on the floor of the derrick, in which case it must be kept fresh and free from gases by the creation of an artificial draught, usually obtained by a steam jet issuing into a chute leading from the bottom of the shaft to the surface. This practice of working in the shaft is to be recommended, as it gives a larger range of motion in dealing with the tubes, and allows the somewhat clumsy tube clamps to be kept in the shaft and away from the confined space on the floor of the derrick, thus avoiding the necessity of fixing a small table over the clamps to enable the driller to conduct the boring and regulate the temper screw.

Derrick.—In order that the boring rods and tools may be lifted and disconnected in long strings, as well as to permit the use of long bailers for raising the oil, a derrick 70 feet high is erected, and from this is built a side structure to contain the engine and boring machine. Four stout poles of untrimmed pine constitute the corner posts, which rest upon and are slightly sunk into square foundation timbers resting on anchor-posts. The corner poles are braced and stiffened by cross-pieces and diagonal braces, and upon the top of the derrick are placed heavy cross-timbers, which have to support the weight of the tools and casing during the progress of the work. Platforms are erected at intervals in the interior of the derrick, upon which the men stand who connect and disconnect the rods and tools from the swivel-hook during the time that the instruments are being raised or lowered, and from these decks there are exits to small projecting stages communicating with a ladder on the outside of the derrick, where men can frequently go for fresh air if the gas is strong, or escape in case of a fountain. Unlike the American mode, the whole derrick and engine-shed are timbered over with light boarding (see Fig. 18).

Derricks are now more frequently constructed on the American principle, being built up by bolting planks together to form the corners, and tied and counterbraced like the other form. A skeleton so made is as strong as one constructed of massive timbers, and it possesses the advantage that in case of fire it very rapidly burns away, and collapses in a heap, whilst the old class of derrick usually resists the fire for a long time, and when the corner poles eventually fall, only partly consumed, they cause great destruction of steam-pipes and other fittings upon which they strike. The built-up derricks, however, take very much longer to erect than the common ones, and as this is a very important matter, especially after a fire, most people still cling to the early type, the cost of which is about the same as the built-up form. Iron derricks have not yet found favour, and it is very doubtful whether they will ever be largely used for boring purposes, on account of their expense, difficulties of construction and repairs, and danger of fire originating from a spark in case of a fountain.

Boring Machines or Frames.—The common Russian boring rig consists of a geared frame, which is arranged with a number of shafts connected by gearing which transmit the various motions to the tools and accessories. The driving shaft is fitted with fast-and-loose pulleys, and receives the drive direct from the steam-engine by means of a belt, or, in cases where an oil-engine or electric motor is used, from a counter-shaft. A second shaft, fitted with a small drum geared to a slow speed, receives the chain with which the tools are raised and lowered, and upon which is attached also the rope leading from the pulley-blocks when they are required for manipulating the tubes. A third shaft, geared to run faster than the others, is supplied with a large drum, upon which is wound the wire rope that operates the sand pump and cleaning buckets for removing the pulverized detritus. Sometimes there is an additional shaft fitted with disc cranks, transmitting, by means of connecting rods, an oscillating motion to a walking beam pivoted overhead, which in turn imparts a reciprocating motion to the boring tools, four distinct crank pin-holes at different distances from the centre of the discs making it possible to give an equal number of lifts to the instruments. Suitably arranged friction clutches and devices are attached for engaging and throwing out of gear the various shafts, and a cord extending from the boring machine to the equilibrium stop-valve of the engine gives the driller power over the steam. Fig. 29 shows a boring machine of good modern construction, manufactured by Messrs. Eisenschmidt, of Baku, which explains clearer than words the general arrangement of a recently designed rig. In detail the frames vary considerably, and whilst some have only a single walking beam over the frame, others have two, and many are arranged for its erection on a separate frame on the opposite side of the well, provided with a stout shaft and massive wooden fly-wheel, which is driven by a belt from a pulley on the main frame. There is always some arrangement on every boring machine by which the walking beam may be thrown back, or to one side out of the way, when the actual boring has ceased and the tools are being lifted. These parts roughly constitute the main elements of all percussion boring rigs and of most of the principal boring machines in the Baku area.

Systems of Boring.—The following systems of boring which have been or are under trial in the Russian oil fields, may be classified thus—

1. *Percussion systems.*

(*a*) Russian free-fall system.
(*b*) American rope system.
(*c*) Wire-rope systems.
(*d*) Canadian pole tool.
(*e*) Galician pole tool (iron).
(*f*) Mather and Platt's flat-rope system.

2. *Rotary drills which extract a core.*

(*a*) Diamond drill.

(*b*) Calyx drill.

3. *Hydraulic processes, where water is made to perform much of the work.*

Chapman's Spindle-Top rig.

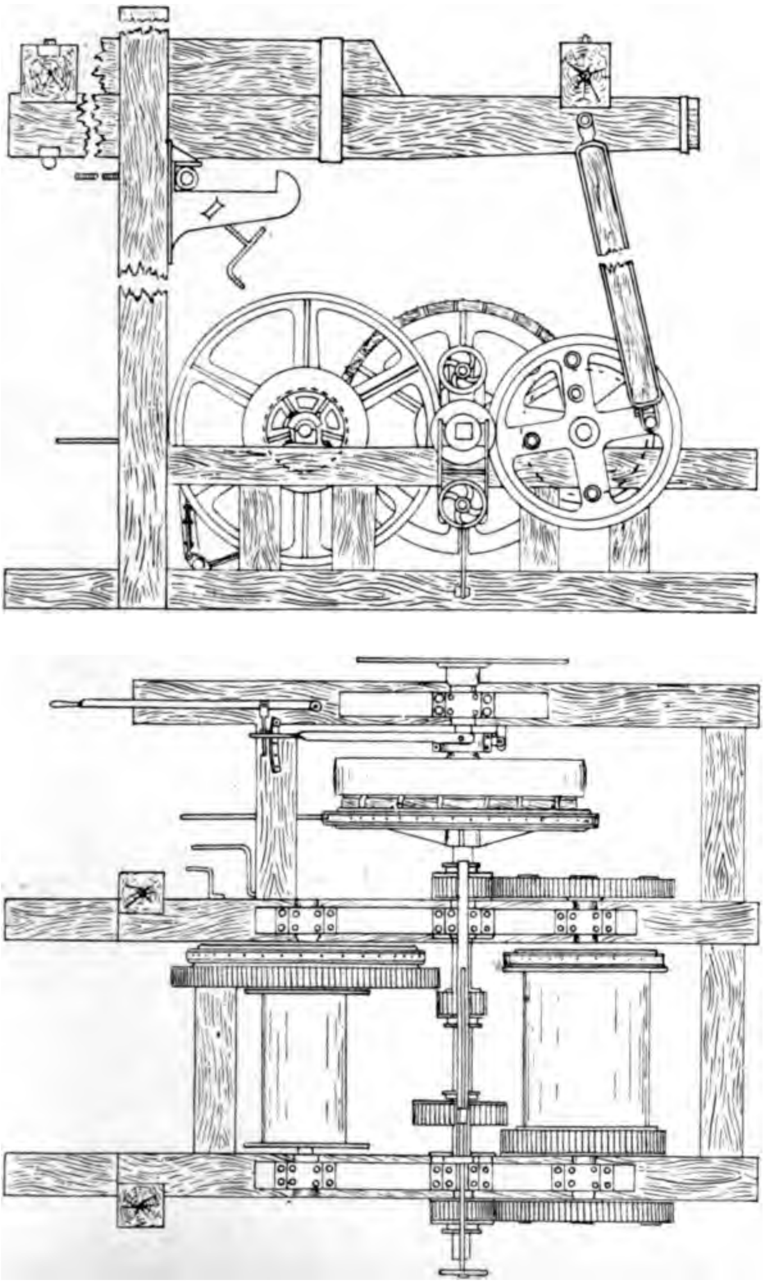

Fig. 29.—A Modern Geared Frame for use with Russian Free-fall Tools.

(Eisenschmidt's Boring Frame.)

I. PERCUSSION SYSTEMS.

(*a*) *Russian Free-fall System.*—The string of tools for a common Russian boring rig is composed of the chisel or boring bit, under-reamer, and sinker rod; then comes the free-fall, which virtually separates the string, connected to 1¼-inch square iron rods that extend to the surface. The whole is suspended from the extremity of the walking beam by means of a combined temper screw and swivel, which allows a free rotary motion and delicate regulation of the feed as the boring progresses. The tools, consisting of chisel, under-reamer, sinker bar, guides, etc., weigh about 1 ton, whilst 1500 feet of rods weigh a little over 3½ tons.

The free-fall, illustrated in Fig. 36, is an ingenious appliance by which the chisel, in conjunction with the sinker bar, can be raised to a certain height and then allowed to fall freely again. The internal sliding portion of the free-fall is connected to the rods, and attaches itself automatically to a projection on the body of the instrument when the lowest point is reached, but it may be disengaged by a slight twist imparted to the rods at the surface during the upward stroke. The consequence is that the boring chisel, sinker bar, etc., can be lifted and released at each oscillation of the walking beam, and from twenty to forty powerful blows a minute can be delivered to the rock, which is pulverised into a fine powder suitable for removal in sand buckets or other clearing tools.

The rate of progress made by pulverizing the strata in this way depends upon the diameter and depth of the bore-hole, and the nature of the formation, for whilst as much as from 20 to 25 feet may be passed in clays and soft beds in 24 hours, not more than 1 or 2 feet can be bored in hard rock or compact dry sands. As the riveted casing used for lining large wells will not stand much driving, under-reaming must be resorted to, in order to secure its freedom for a considerable depth.

The common Russian under-reamer is shown in Fig. 30, where it will be seen that two knives or cutters are forced outwards from a wrought-iron body by the action of a powerful spring actuating them through the medium of two linked rods. The cutters are easily interchangeable, and are generally designed to make a hole, when fully extended, 2 or 3 inches larger than the internal diameter of the lining tubes. The cutters are made of the best quality steel, and are so designed that when forced inwards and inserted into the top length of casing, the sides and not the cutting edges of the cutters come into contact with the sides of the tubes. Mr. Biering, an eminent boring contractor in Baku, patented, several years ago, a combined chisel and under-reamer, which is also illustrated (Fig. 31), manifestly possessing many advantages that must be at once admitted by every one. The combination form allows the lining tubes to be kept very close to the chisel—a feature of obvious importance in some classes of ground, and it also makes one joint less to screw up and disconnect, and consequently one weak spot less to fracture when boring.

The sinker bar is a heavy rod of iron from 3 to 4 inches square, about 20 feet long, fitted with guides top and bottom, which nearly fit the casing, and its purpose is to add greater weight to the chisel, and keep the bit from running out of vertical. 1¼-inch square rods are almost universally employed for the Russian free-fall system of boring, and they are generally manufactured in 21-feet lengths, with taper screwed ends and sockets; they are slightly thickened, and given a shoulder under the threads where they may rest on forks whilst being connected and unscrewed.

Good Swedish iron gives the best results for boring rods, but the great vibration to which they are subjected when in a vertical position rapidly crystallizes the iron, and makes it highly magnetic and exceedingly brittle. If the rods are occasionally annealed in a suitable furnace, their condition is improved, but in any case, after annealing or welding a joint, they should always be tested in the shop, as endless trouble will thereby be saved. A fire-brick annealing furnace may be made long enough to take the rods, and may be heated by means of a burner using oil fuel.

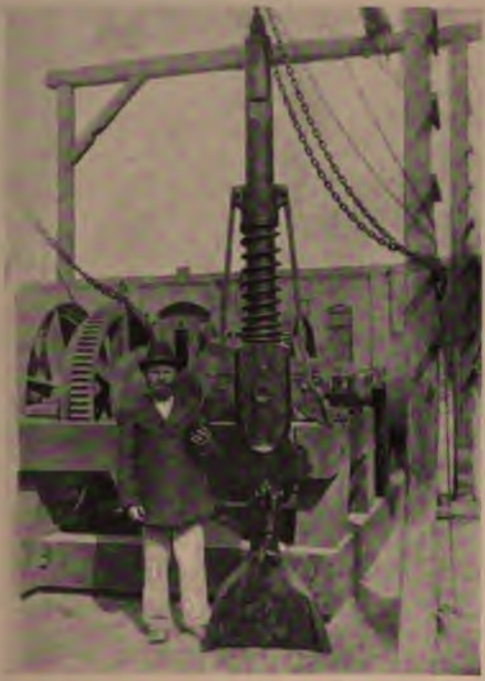

Fig. 30.—Common Baku Type of Chisel and Under-reamer.

The tools and rods are lowered into the well from a drum (fitted with a powerful brake) by means of a swivel-hook with a safety catch attached to either a 1¼-inch welded link chain (generally of English hand-make), or a 1¼-inch to 1½-inch wire rope long enough to reach from the drum to the mouth of the well. After boring from 5 to 7 feet, the tools are raised, and the rods, disconnected in couples 42 feet long, are placed vertically at one side of the derrick, where they are prevented from falling by a curved guard fixed to an upper platform, where a man is stationed to arrange them neatly and release the hook. As each pair of rods is lifted, a strong wrought-iron fork is pushed forward, which supports the weight of the tools and remaining rods, before the men commence to uncouple the screwed joint with long wrenches. The cleaning tools for lifting the pulverized material, special tools, and fishing instruments, are practically the same for all percussion boring methods, and will be described later on.

(*b*) *American Rope System.*—Although the American drillers met with most conspicuous failure in their Baku attempts, there were some people who saw that a modification of the principle might be successfully applied, and gave much attention to its development. In the first trials with the American drill, the ordinary American tools only were used, and the lining tubes were driven, by means of driving monkeys, into the bore-hole, where they were, almost without exception, fractured before a depth of 200 feet had been reached.

The character of the strata in the Baku district will not allow them to stand for any great distance without caving, and no amount of driving will induce tubes to move when once firmly held. In Grosny the American drilling can be and is extensively adopted, as the ground is very compact, and neither caves in nor slips to a dangerous degree, and a single string of casing may be kept free for 500–800 feet with ease.

Rope drilling does not lend itself well to under-reaming, and it is quite certain that without the attachment of some form of under-reamer the system cannot be locally successful. Biering's patent combined bit removed many obstacles, and it is the patentee of this chisel who, firstly with Nobel Brothers, and afterwards in private business, has brought to a workable and highly successful issue the American method. At first only small holes were drilled; but by degrees the diameter was increased to 26 inches and 28 inches with the system, and wells were bored at a rate exceeding in some cases that attainable with the Russian rig. Some rigs have been constructed combining the principal features of both the American and Russian systems, and when the ground is unsuitable for rope boring, the rods are used instead. The chief advantage gained by the rope method is the rapidity with which the tools may be raised and lowered, compared with rods, and the diminished risk through absence of so many feet of iron rods and numerous screwed joints. Rope drilling requires more skill than ordinary boring, and it is quite necessary to have always an experienced and intelligent master of more than average ability to superintend the work. If so much time is saved in lowering and lifting the bit, and there are less breakages to contend with, one naturally inquires why it is that the rope system does not produce a better average speed than rod methods, and the very fact that faster progress is not, as a rule, obtained, is evidence that the system, as a whole, is less suitable for the local strata than the free-fall device. A 6-inch Manilla rope is employed, and the string of tools is composed of the boring bit and under-reamer, heavy sinker bar with removable guides to suit any diameter of casing, jars, a striking bar, and rope socket.

The jars are a curious device, consisting of two powerful links about 6 feet long, which slide one in the other and divide the tools into two separate sections. When the tools have been lowered to the bottom of the bore-hole, the rope is

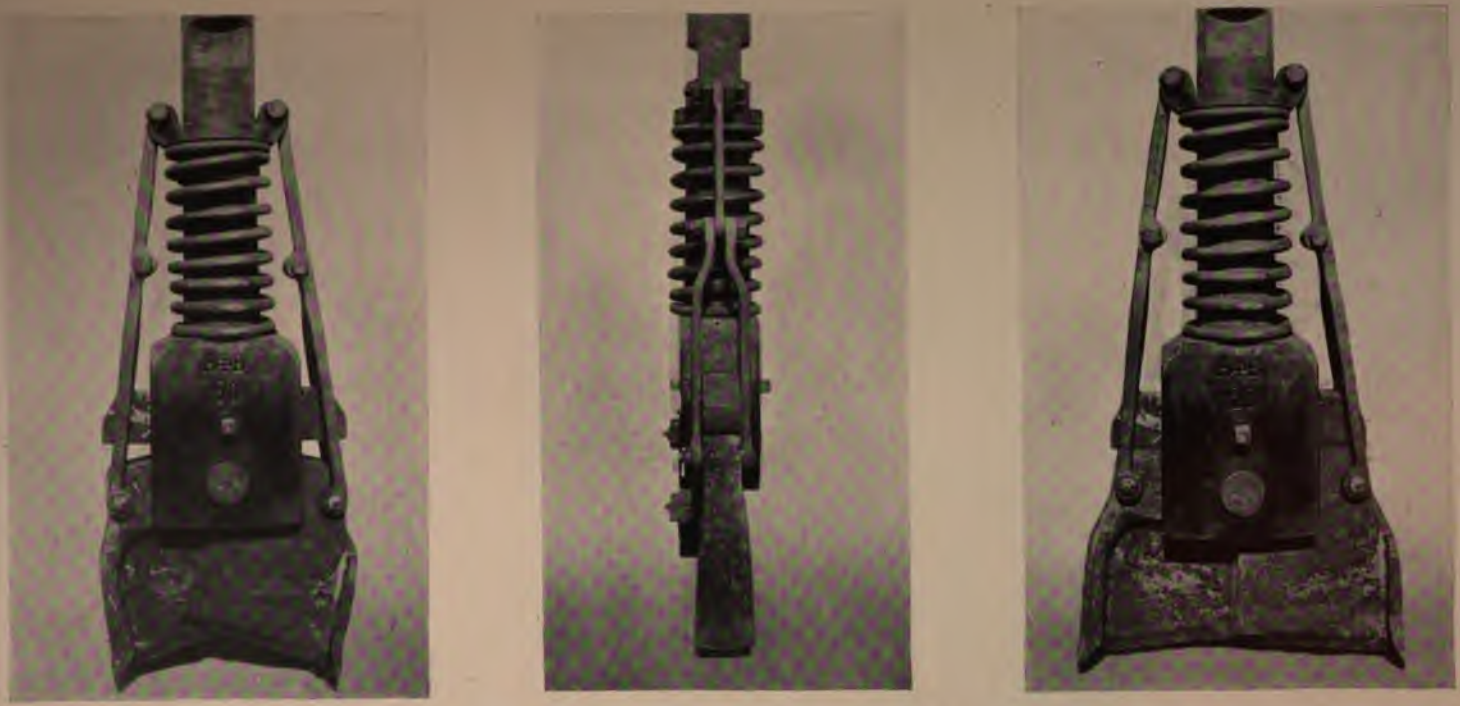

Fig. 31.—Biering's Patent Combined Chisel and Under-reamer.

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slackened out slightly and clamped firmly to the temper screw suspended from the walking beam. The object of the jars during work is to direct a powerful upward blow at each oscillation of the walking beam, which prevents the chisel from sticking in the stratum after its downward stroke; for a bit would often never be released by a direct pull on a hemp rope. The chisel, aided by the weight of the sinker bar, thus delivers the working blow, and the hitting bar and upper link administer the release hit, whilst a continuous rotary motion, transmitted to the rope at the surface, ensures the regular work of the drill. When working in very hard strata and rock, the jars are not brought into action, and more rapid progress may be made by keeping the rope quite taut, and allowing the tools to deliver a series of blows by the momentum gained in the descent in conjunction with the spring of the Manilla rope. The exact action can be illustrated by suspending a weight from a piece of elastic, when it will be found that, by transmitting a slight reciprocating motion to the elastic, the weight may be made to strike the floor with great force near the extreme limit of the elasticity. When a bit becomes fast, and cannot be released by a number of blows, more loose rope is let out and a longer stroke given to the walking beam, after which the machine is put in motion, and the harder delivery of the blows usually has the effect of freeing the chisel. During the Spanish-American war, the price of Manilla ropes rose so much, and their purchase was so difficult, that *wire-rope* boring received an impetus, and was brought more prominently forward by people who used hemp ropes.

Fig. 32 shows an excellent hempen rope boring machine made by Messrs. Mather and Platt of Manchester, who have carried down borings as large as 33 inches diameter by its employment. The working of the tools is similar to that described above for other American styles of boring plants, the elasticity of the rope being made use of to perform part of the work.

(*c*) *Wire-rope Systems.*—For many years wire-rope boring was only conducted by the old-established Baku firm of Lentz, who were the originators of a patent successfully worked by them for a long time. Lentz's system differs from all others in a number of details, including the geared frame itself, and a glance will suffice to show that it is the result of the inventive genius of one firm, which has copied nothing from outside sources. On a specially designed frame is mounted a large drum about 10 feet in diameter, upon which is coiled the 1¼-inch steel-wire rope employed to lower and raise the tools. The needful movement is imparted to the suspended tools by first drawing a bolt and allowing the winding drum to revolve freely on the shaft, and then engaging a connecting rod to one of the arms, which is given a horizontal motion by a disc crank operated from the driving shaft. The drum, by this means, is caused to perform a fraction of a revolution to and fro, which amount can be increased or diminished by changing the position of the crank-pin on the disc. The tools used are much the same as for an ordinary Russian rig, but the chief peculiarity is an ingenious free-fall contrivance placed immediately above the sinker bar, which automatically imparts a rotary motion to the drill during the operation of boring. The feed is applied by a special arrangement of worm-wheel and gearing in the summit of the derrick, actuating the nut of the screwed spindle from which the pulley is suspended. A cord from the floor, communicating with the top gearing, renders the operation of feeding the tool very simple, and does away with any necessity for temper screws and constant disconnecting of the wire rope. Lentz's boring machine has given very good results in the past, and it has the decided advantage that rods and ordinary tools can be used, without any alteration, if desired, or if rendered expedient by the character of the strata.

Another wire-rope system that has been introduced into the oil fields is simply the American principle used with a wire rope instead of a hemp rope. A special manufacture of wire rope, made of left- and right-hand strands plaited together, is required to prevent untwisting and kinking during the work, and as only a very limited amount of rotation can be imparted to a wire rope without damage to the strands, the top end must be uncoiled from the drum and left free in a coil above the hand levers. This process has, in the hands of a skilful attendant, worked satisfactorily; but it is an obvious objection to have to entirely disconnect the wire rope from the main drum at each operation. Mr. Biering has recently (1902) patented a device for automatically rotating the bit, the apparatus being placed immediately above the string of tools, consequently acting like Lentz's device, and needing no twisting from the surface.

(*d*) *Canadian Pole-tool System.*—The Canadian system is almost identical with the common American rope rig, the only difference being that wooden (pine) rods with screwed iron ends are used instead of a Manilla rope. This method has been successfully employed in Grosny and some other newly developed lands, but it has not met with the same measure of success in the Baku fields, although more than once tested. The chief objections to its adoption are the difficulties of securing reliable and skilful operators—for the process requires as much skill as the American rope plant—and the large diameter of the wells, for which it is ill adapted. The advantages claimed for the use of pole tools are—reduced weight of the suspending material, as the wooden poles are considerably lightened when immersed in liquid, and the delivery of a more direct blow, and at a quicker speed than with a hemp rope. The wooden poles are unaffected in quality by the vibration like iron ones, and the action of the tools and rotation of the bit can be felt more delicately than with a hemp rope.

(*e*) *Galician System.*—This process is simply a modification of the Canadian arrangement, where, in the place of wooden rods, very light iron drilling rods are used with screwed ends. This method has been tested in the Baku oil fields, and has worked with moderate success, but there is no increase in the speed of boring; in fact, the rate has not reached the average of local rigs—a feature explained by the introducers to be due to absence of skilled attendants. An experienced driller will connect and disconnect the rods at a surprising rate, and will bore from 20 to 30 feet a day when the diameter of the well is small.

(*f*) *Mather and Platt Borer.*—An attempt was made in 1898 to introduce Mather and Platt's flat-rope system, but it was eventually abandoned as impracticable in its present form. The boring is performed with a special class of tools suspended from a flat hemp rope, the motion being imparted by a piston working in a steam cylinder to which steam is alternately admitted and exhausted by hand or automatically. The tools are raised and lowered from a large drum upon which the flat rope is coiled, operated by gearing driving from a double

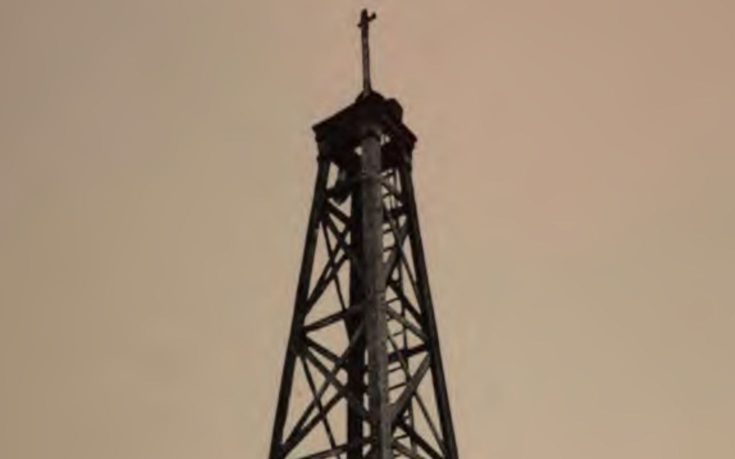

Fig. 32.—Mather and Platt's Round-rope Boring Machine.

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cylinder steam-engine mounted in the base of the frame. When the tools have been inserted in the well, the rope is clamped to a feeding device, by the agency of which the tools may be steadily lowered as demanded by the progress of the work. The stroke of the tools is decided by the position of the exhaust valve, which can be shut at any point of the stroke, the enclosed steam in the cylinder cushioning the descent of the tools, which rapidly fall by gravity on the release of steam below the piston.

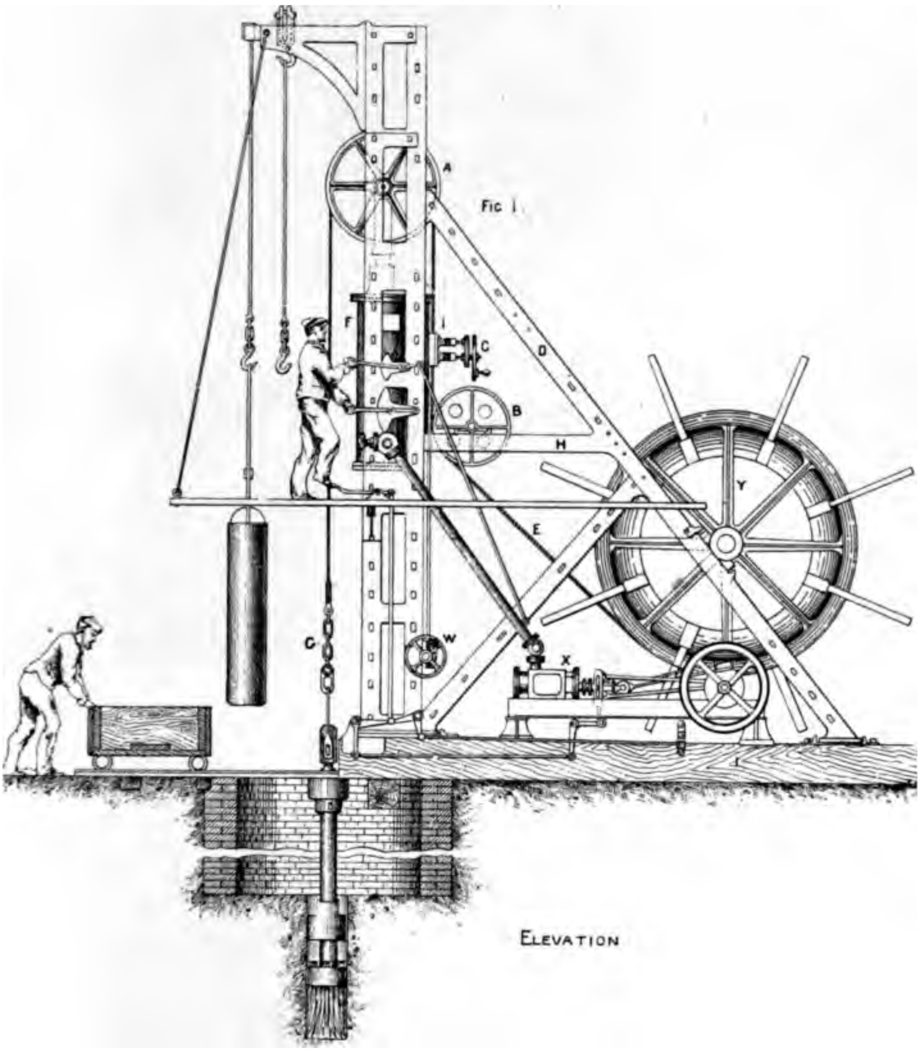

Fig. 33.—Mather and Platt's Boring Machine.

The tools are of peculiar design, being steel discs into which are inserted a number of chisel-pointed picks about 12 inches long, butting with a shoulder on the under side, and held by a couple of nuts on a screwed end extending through the disc. The boring bar, to which the cutters are attached, is provided with guides to ensure true work, and has a peculiar ratchet attachment at its upper end, which gives the chisel a slight rotary motion at each stroke. Fig. 34 shows the form of ratchet, which consists of two cast-steel toothed ratchet blocks secured firmly to the boring bar, between which is a third double-toothed ratchet that slides freely over the bar, but is fitted with the hook by which the tools are suspended. The pitch of the teeth in the fixed ratchets is simply in line, but the teeth on one side of the sliding ratchet are placed half a tooth ahead of the other. When the tools are suspended, the top two ratchets are in contact; but when the tool strikes the ground, the free ratchet falls into the lower ratchet, and is pushed one half-tooth ahead. On lifting, the loose ratchet occupies the next tooth to the one formerly occupied, and as the rope untwists to become straight again, the bit is slightly rotated.

The Mather and Platt machine is not fitted with an under-reamer, and the experiments made with those of local construction, in conjunction with the usual bits, were not a success on account of the failure of the ratchets to work regularly. The knives of the cutter often break when hard, irregular rock is met with, and altogether the system seems to be unsatisfactory for local use.

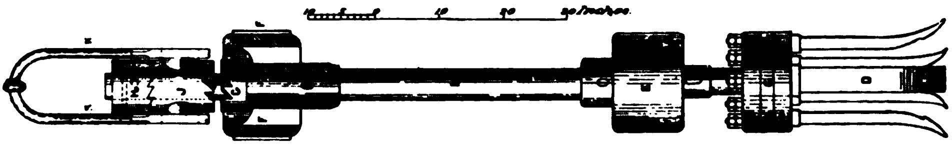

Fig. 34.—Boring Bar and Cutters.

2. ROTARY DRILLS.

(*a*) *Diamond Drill.*—This common and valued drill is the best known of all rotary boring drills, and is used for boring purposes of all descriptions throughout the world. It is quite unnecessary to give a description, for, as every one knows, the boring is executed by a steel crown (studded with black diamonds) in the presence of a powerful flush of water, the core so produced being preserved and raised in a barrel fixed above the crown. Hollow rods are continued to the surface, where they are rotated by a suitably geared frame driven by an engine. The drill has been tried in the Baku fields, but it has been proved to be quite unsuitable for the local strata, apart from the objections of its enormous expense, the fabulous price of such large diamond crowns as are needed, and the great skill required in its manipulation to prevent accidents.

(*b*) *Calyx Drill.*—The calyx drill is one of the latest introductions into the oil fields, and is a system imported from Australia, where excellent results have been and are obtained by its use. It partakes of the type of the diamond drill, and aims at the extraction of a core—an advantage every one will admit—and necessitates the use of a powerful water-flush. The peculiar features of the drill lie in the construction of the cutter, of special form, which takes the place of the diamond crown, and the *débris*-holder, called the calyx, into which all the loosened particles collect. The cutter is made from a collar of extra quality steel, into which is cut a number of teeth of special shape, which are impelled to seize hold of the stratum by the application of weight applied at the surface. A rotary motion is transmitted to the bit by hollow rods extending to the top, thus causing the formation of a core which is preserved in the core-barrel until separated and raised from the well. Above the core-barrel, attached to the hollow rods, is the calyx, which is in reality simply a long cylindrical vessel of the same diameter as the core-barrel, which, in addition to guiding the bit straight, receives the chippings and particles resulting from the action of the cutters. Water is forced through the hollow rods by a pump at the surface, and emerges at the mouth of the bit at a high speed, which is maintained through the confined space surrounding the core-barrel and calyx. When the comparatively motionless portion above the calyx is reached, the particles in suspension fall into the vessel, and the water traverses the remaining portion of the bore-hole to the surface, where tubs are placed for its reception and settlement prior to re-use.

Most of the objections which will be enumerated apply to other water-flush systems when boring for oil, but the first failures attending the use of the calyx drill were partly due to unsuitable machinery and tools, which were designed for only small diameters. Whilst water-flush systems are excellent for wells of small diameter, their value is greatly reduced in borings of large size, owing to the enormous quantity of flushing water required, and the loss through percolation into the strata. Sands of a very porous character are met with at frequent intervals in the Baku oil belts, and there is considerable risk of the water supply failing entirely in its object, and leading to the loss of the calyx and core-barrel in a manner which might entirely prevent their recovery. Perhaps the most serious obstacle to the use of such drills is the flooding of the oil beds when encountered, and the irrecoverable injury sustained by adjacent bailing wells about that depth. This has actually happened in several instances, and surrounding wells have suddenly turned to water, and yielded no oil, and have had to be abandoned or deepened. Even in such a comparatively small operation as washing out an instrument, neighbouring wells near that depth are often seriously affected and sometimes ruined entirely.

Another difficulty presented itself when it was found that, without under-reaming, the tubes could not be made to pass many sagenes; and this led to the modification of the cutting head, the addition of an under-reamer, and the attachment of a new core-grabber. In the first drill the core was disconnected and gripped by throwing down the water-flush pipe a quantity of particles of stone, which were forced around the core by the water pressure. The calyx drill, although working well in clays and clayey mixtures, did not give such good results in the very hard sandstones as was expected, and as the rate of boring, taken as a whole, was far exceeded by the old system, its use did not extend. There appears to be a serious element of risk in any process where a vessel occupying the full bore of the hole is used, and it would be interesting to see what would happen to the tools in the event of a sudden fountain, or an instantaneous rising of a huge sand plug such as occasionally occurs. It may be argued that the water-head precludes all possibility of such an event, but it must be noted that fountains and plugs do rise in this manner even where the wells are full of water. Unless the force of the gas blew the whole apparatus from the well, it is doubtful whether the instruments would ever be raised.

3. HYDRAULIC PROCESSES, WHERE WATER IS MADE TO PERFORM MUCH OF THE WORK.

Chapman's Spindle-Top Rig.—This system has been extensively adopted in Texas on the Spindle-Top region, and has proved very successful for passing great beds of quicksands. Its trials at Bibi-Eibat cannot be said to have been successful, and, indeed, it is doubtful whether it will ever meet with success for such large diameters, whilst it possesses the objections of other water-flush systems. The surface apparatus consists of a heavy, geared frame, which revolves hollow drilling rods, through which a powerful flush of water is forced during work. The chisel, or bit, has two expanding steel wings which loosen the strata, and the water conveys the disintegrated material to the surface; but if a hard formation is encountered, another class of drill is needed, which must be provided with an under-reamer to assure of sufficient space being left for the passage of the lining tubes. This drill should meet with greater success in Grosny, and in wells of smaller size, where the tubes might themselves be fitted with a cutting shoe and revolved in the face of a powerful flush of water.

Other hydraulic systems of boring have been and are being tested in the Baku oil fields by several leading firms, but the author is in a position to say that so far no great success has rewarded the efforts of these more enterprising explorers.

Trueing the Well.—The first column of lining tubes acts as a true guide for all the subsequent casings, and, consequently, no reasonable precaution must be omitted to ensure its absolute verticality. The tube is forced into the alluvial surface ground with a heavy screw, that presses against a massive cross-timber slung over the mouth of the well and firmly secured by anchor-posts, the earth from the interior of the casing being occasionally cleared out with augers. The arrangement is shown in Fig. 35.

When the tubes have reached a depth of 40 to 50 feet, the verticality must be constantly tested by means of a device (Fig. 35), consisting of two discs of iron connected by spring guides which accurately fit but pass freely down the tubes. On the upper surface of the top circular disc is placed a layer of some soft mastic-like mixture, which will retain any impression imprinted on its surface. The apparatus is lowered by two cords to the desired position, and fixed, and a sharp-pointed, heavy plumb-bob is lowered from the centre of the well, and when quite stationary and free from oscillation, allowed to impress a centre dot upon the plastic substance, the position of which shows accurately the amount the well is out of plumb. If the tubes do run out of the vertical, they must be drawn back, the bore-hole filled up with sand or stone, and the boring recommenced from the point where they first showed deflection. If repeated trials fail to rectify the error, the site of the well must be changed, or the work be continued with a tube of smaller diameter.

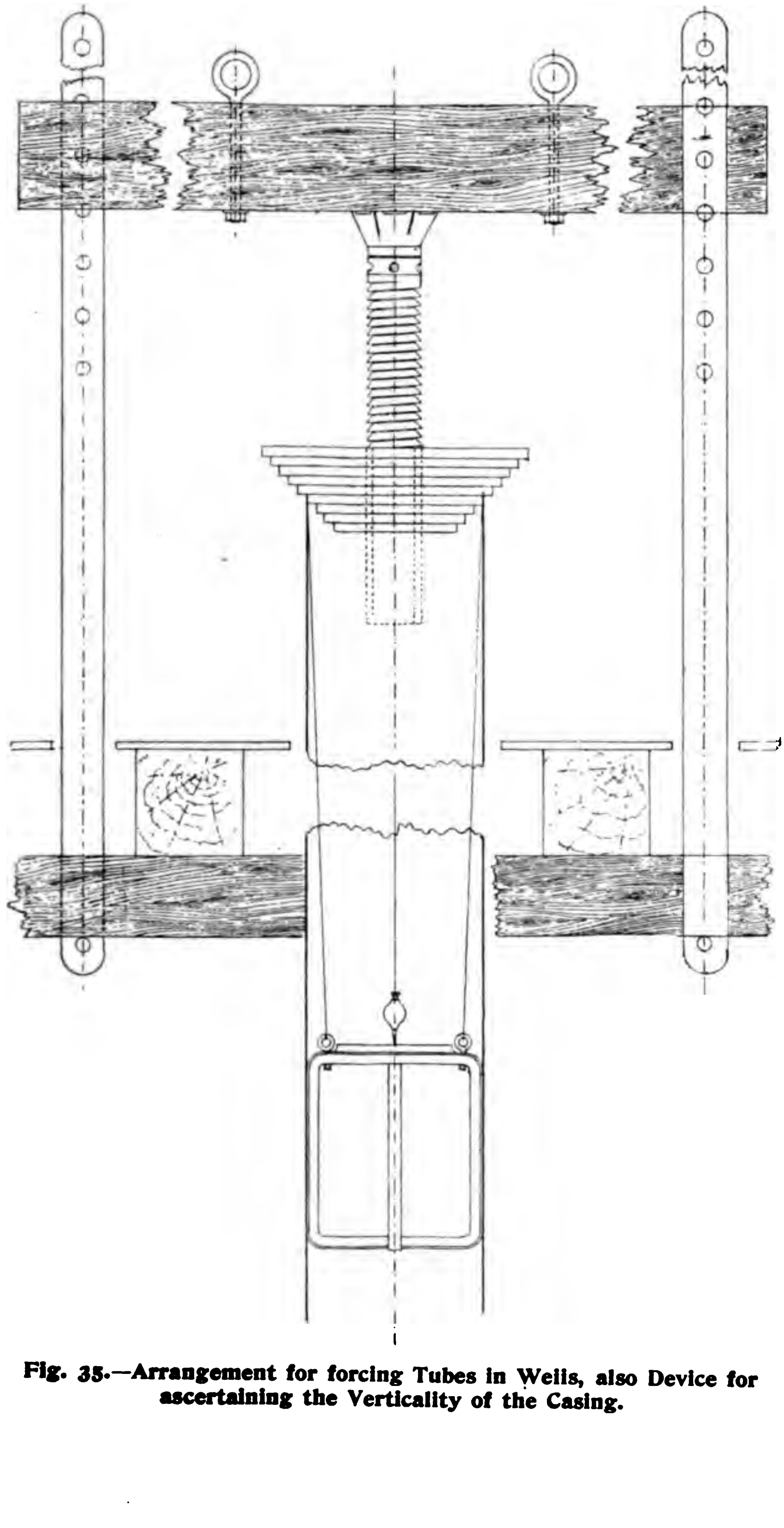

Fig. 35.—Arrangement for forcing Tubes in Wells, also Device for ascertaining the Verticality of the Casing.

Cleaning the Débris from Wells.—The pulverized fragments resulting from all percussion methods have to be raised by special tools, of which there is a large variety to suit different classes of strata. The sand pump is one of the best-known and most useful tools for cleaning out the wells, and is made in many different forms. The most common Baku pattern is composed of a barrel (tubing is generally used), the lower part of which is of larger diameter than the upper, and fitted with a flap and common lift-valve bedding on to a seating which is detachable. In the upper, smaller part, a piston works, connected to a long iron rod which passes through a guide at the top, that also acts as a stop, and prevents the complete withdrawal of the piston from its chamber. When the pump is lowered to the bottom of the well, the piston sinks to the lower end of the cylinder until its further progress is stopped by a collar on the rod, but on lifting, the partial vacuum produced beneath the plunger causes the mud and sediment to be drawn into the lower barrel, where its exit is prevented by the valve.

A more general and simpler form of well-cleaner is the "American pump or bucket," which is merely a piece of tubing about 6 feet long, provided with a removable flap valve at the bottom, and fitted with a guide at the top for steering the rod of the piston. The piston is packed with old hemp rope, and the rod is made with a swivel joint at its lower extremity, which will pass freely through the top guide, and allow the bucket to be turned upside down, and consequently emptied, by slipping a suspended hook into a hole made for the purpose at the bottom. If the pulverized material is in the form of a thick mud, an ordinary bailer, or a stouter form of bailer made of tubing with only a lower valve attached, enables the well to be thoroughly cleaned. There are innumerable forms of sand pumps and buckets for which special advantages are claimed, but where, as occasionally happens, the material cannot be raised by these, augers are lowered on the rods and rotated to scoop up the sediment. Augers are simply cylindrical vessels provided with a cutting edge at the bottom, which directs the material into the body when rotated, but to ensure the admitted detritus not falling out during the upward trip, a flap valve which closes on raising is sometimes placed immediately above the cutting edge. Fig. 36 shows some Baku forms of boring requisites.

Fishing for Lost Tools, etc.—The greatest skill of the well-driller is required more for the fishing of lost instruments than for the boring, and it is in this work that the ability, endurance, and perseverance of the operator are tried. Whatever the quality of the iron and steel used, and however good the quality of the workmanship expended on the boring instruments, breakages will occur, but although the greater number are of small importance and are easily overcome, some are of a most intricate nature, and occupy months and even years of patient toil to remedy. The fishing tools include a more expensive collection of instruments than the boring tools, if anything approaching a complete set is stocked, and upon the possession of these implements, ready for instant use, much of the success in boring depends.

When an instrument breaks or becomes detached in the well, the first operation is to lower a seal or impression block, to ascertain minutely the position of the fractured or unscrewed part. An impression block is a bell-mouthed, sheet-iron vessel filled with a resinous material capable of receiving an impression of any article with which it comes in contact. The large end of

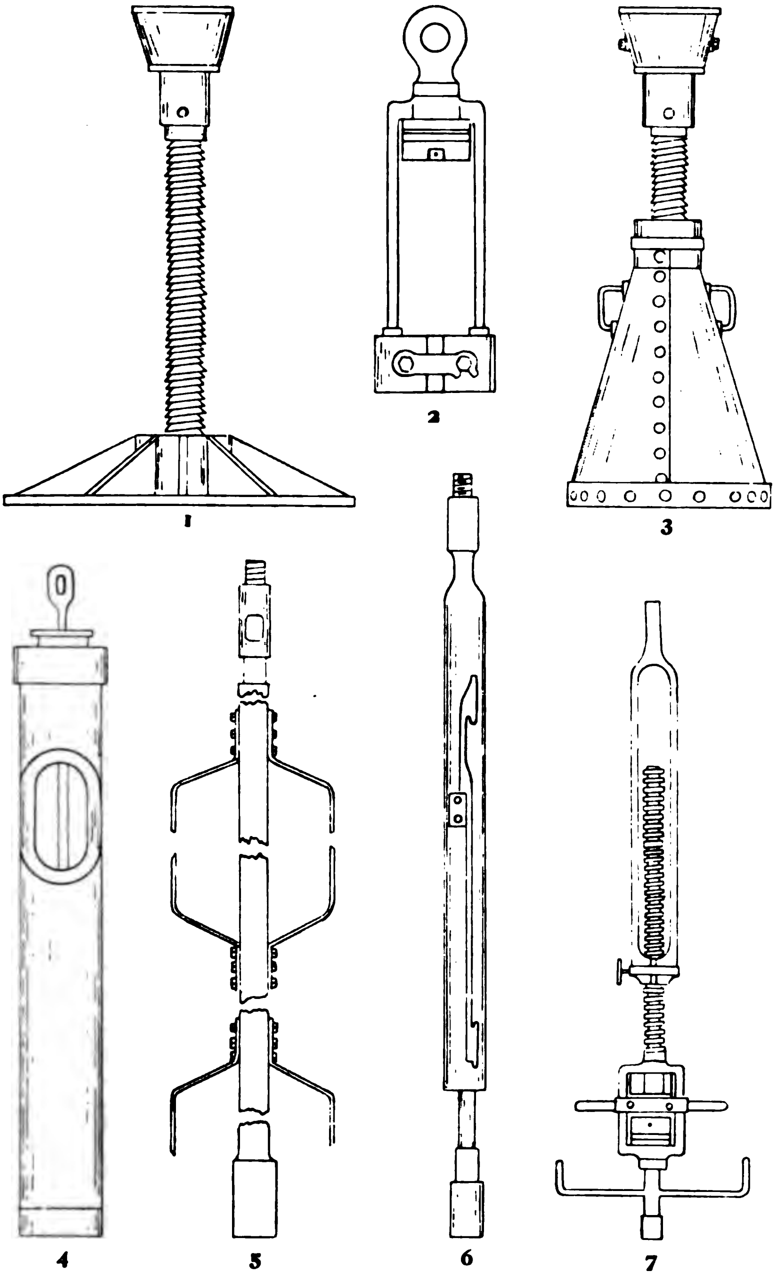

Fig. 36.—A Few Common Boring Requisites.

1. **Screw for forcing tubes down a well.**
2. **Swivel-hook for raising and lowering rods.**
3. **Screw-jack for raising tubes.**
4. Sand pump.
5. Sinker-bar and guides.
6. Free-fall.
7. Temper screw and swivel-handle.

the cone is a trifle less than the diameter of the well, and the upper part is fitted with a screwed end for connecting to ordinary 1¼-inch rods, the lower rod being provided with guides to keep the block central, and prevent its becoming damaged in transit to its destination. If the lost or disconnected boring tool is lying to one side of the tubes, it is often necessary to push it into a vertical position before the fishing tools are lowered, and this end is usually attained by inserting a bent bit, and rotating it round the upper part of the lost instrument. If the tool will not remain in a central position, a few balls of clay may be dropped round it when the side bit is in operation, and this usually ensures its remaining in the centre until the fishing tool has secured a hold.

The most frequent accident is, without doubt, fracture of the iron boring rods, which, if occurring during boring, is generally a simple matter, but if taking place when the tools are raised some distance, becomes very much more complicated on account of the twisting and buckling the rods suffer in the fall. In the first case, when the tools will in all probability be free, either an internally screwed taper socket, finished like a die, is lowered with a conical, bell-mouthed guide that will direct it on to the rod end; or an open socket fitted with two hinged flaps is slipped down over the rod end, which it grips firmly when raised. Even a plain curved hook lowered on the 1¼-inch rods may be sufficient to secure a firm enough hold beneath one of the collars on the lost rods to effect recovery, if the tools are not held by cavings of ground.

If the tools are firmly embedded in the ground through a fall of some considerable distance, the rods must be disconnected and removed in lengths by lowering left-handed screwed sockets on reversible fishing rods. When the last rod has been disconnected and the tools themselves are reached, a screwed collar, which will fit the thread on the instrument, is lowered on strong rods, and, after firmly screwing up, pulley-blocks or jacks are applied at the surface.

One of the most valuable and important fishing tools known—indeed, it might be termed the best tool in existence—is the instrument called the slip-socket, which is an apparatus of American invention, that finds its special value in the following features:—

(1) It will never fail to seize the lost object, if properly arranged previous to lowering.

(2) The greater the force applied, the firmer does the instrument grasp the object.

(3) It can be simply and safely released and raised if the object refuses to move.

Fig. 37 illustrates a beautiful tool of this type manufactured by Bepple Bros. of Baku, who exhibited a specimen at the Tiflis Exhibition in 1901.

The details will be observed from the figure, but the special action is that when the end of the lost object touches the central spindle (after the slip-socket has been lowered over the object) a catch is released, the slip pieces drop into the taper socket at the bottom and seize the object between them, and the harder the pull the tighter will be the grip. If, however, the slip-socket is lowered or driven down again, the hold is released, for the object strikes the spindle and raises the slip pieces, their fall being prevented by a catch which automatically holds them. To reset the slip-socket it must be raised to the surface.

When fishing for lost instruments, it is usual to lower the fishing tools on special rods, 2 inches to 2½ inches diameter, constructed with a protruding tongue on one end, and a groove of corresponding proportions on the other, and connected together by a loose-screwed collar. Fig. 38 shows such a fishing rod, and its special construction allows it to be rotated in either direction without danger of the collar unscrewing.*

Often a sediment of sand or other suspended material settles firmly around the lost tool, or a plug of sand runs in and grips the bit firmly before any measures for its recovery can be adopted, and prevents its abstraction in the ordinary way. An accumulation of this nature may be sometimes cleaned out by lowering small buckets and augers, and patiently cleaning away the collection, but more usually 2-inch or 2½-inch tubes are lowered to the plug, and, whilst a powerful water-flush is forced through them, they are gently lowered, a pull being applied simultaneously to the fishing rods and tools, which have previously been strongly attached. If a chisel breaks off short just above the flattened portion, a pair of claw-tongs, somewhat similar to those described for lifting lost bailer-valves, is lowered, and the massive piece of steel may often be raised.

If all methods fail to lift the tool, the last resource is to cut it up or drive it away to one side out of the path of the boring, if the softness of the strata permits this. It is wonderful how easily massive tools may be driven to one side in some cases, and how large instruments totally disappear and never reappear. In one well under the author's supervision, fishing operations continued without intermission for 9 months to recover a lost chisel, and eventually the work was

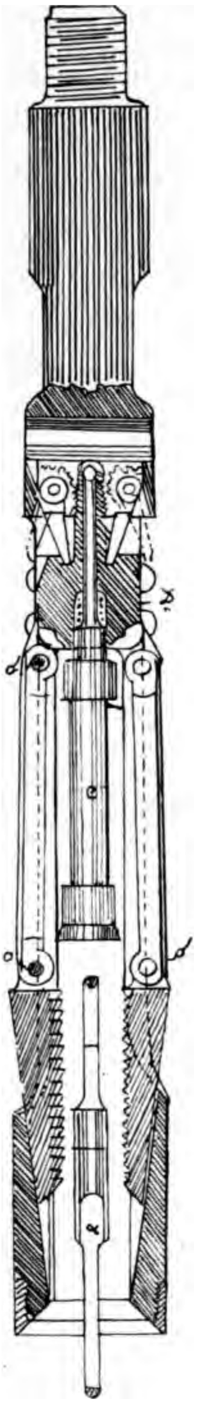

Fig. 37.—An Excellent Type of Slip-socket, made by Bepple Bros. of Baku.

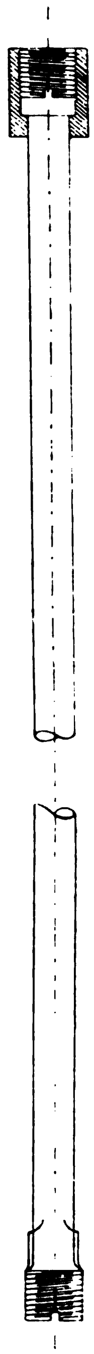

Fig. 38.—A 2½-inch Fishing Rod.

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* Even with these rods the author has experienced cases where the sockets have become unscrewed during fishing operations; but this has always arisen from the rods lying under extreme tension to one side of the well, and the consequent friction between the collars and casing being sufficient to prevent some of the rods rotating when the upper ones were revolved in a negative direction at the surface.

stopped in desperation, and bailing was commenced to remove a few hundred poods of oil which were in the well. The bailing had not continued many hours before there was a fountain, and the well yielded by bailing and flowing 10,000 to 14,000 poods a day. A year later, when the same well was repaired and deepened, no trace of the lost tool was found, and the boring was carried to a deeper stratum.

A string of tools and rods is often dropped several hundred feet, or even a thousand feet, through some carelessness of the operators or the fracture of some surface fitting, in which case fishing is often seriously complicated, and even the well much damaged. In one instance a chisel, under-reamer, etc., fell from near the surface, and the knives of the under-reamer, coming into contact with some exposed edge of casing, opened after reaching a fearful velocity. The result was that about 70 feet of 14-inch casing were torn into two separate pieces, making it necessary to lift the whole column of tubes and replace it, besides spending many weeks in fishing for the tools.

An instrument is occasionally arrested in its fall by jamming in the casing after passing only a portion of the way to the bottom, and its position, if it is not immersed in liquid, may often be nicely seen by the reflection from one or two mirrors placed at an angle which will illuminate the interior of the well.

Recently, a Baku engineer, Mr. Loran, has taken some photographs of lost instruments, and has, in some cases, obtained very successful negatives. A specially constructed stereoscopic-photographic apparatus is lowered to a point near the lost tool, and, after an electric light has been switched on, a negative is obtained. The arrangement is very ingenious in its details, and Mr. Loran, who kindly explained the apparatus fully to the author, stated that it took a considerable time to bring it to its present state of improvement. An internally blackened, bell-mouthed vessel, at the small upper end of which is fixed the stereoscopic camera, and at the sides of which are fixed two small electric lamps with shades reflecting the light downwards, is attached to a sinker rod with guides. Encased in an air-tight chamber above the photographic device is an electric accumulator which supplies the light, and interposed in the circuit is a small clock that can be regulated to produce contact at any desired time, switching on the light and opening the camera-shutter at the same moment. Above this is placed a cylinder in which compressed air is stored, leading by minute tubes to the bell-mouthed photographic vessel beneath. By a clever device, a quick upward or downward motion of a few inches causes a disc, nearly equal in size to the well, working freely on the central spindle, to rise or fall, and transmit a motion to a lever which actuates an air-valve leading from the air-vessel. The pressure of air must exceed the pressure due to the submergence of the apparatus in the liquid, and on the air-valve being opened, the fluid is displaced in the bell-mouthed vessel, and an undisturbed view of the lost article is secured. After an exposure of one or two hours, the air is shut off by a repetition of the before-mentioned jerk, and the apparatus raised. Fig. 39 shows a few specimens photographed by Mr. Loran in the Baku oil fields.

To describe fishing properly would occupy a volume, for almost every case has some peculiarity, and needs some slight modification of the usual appliances kept on hand; but the boring master should use only fishing apparatus of the

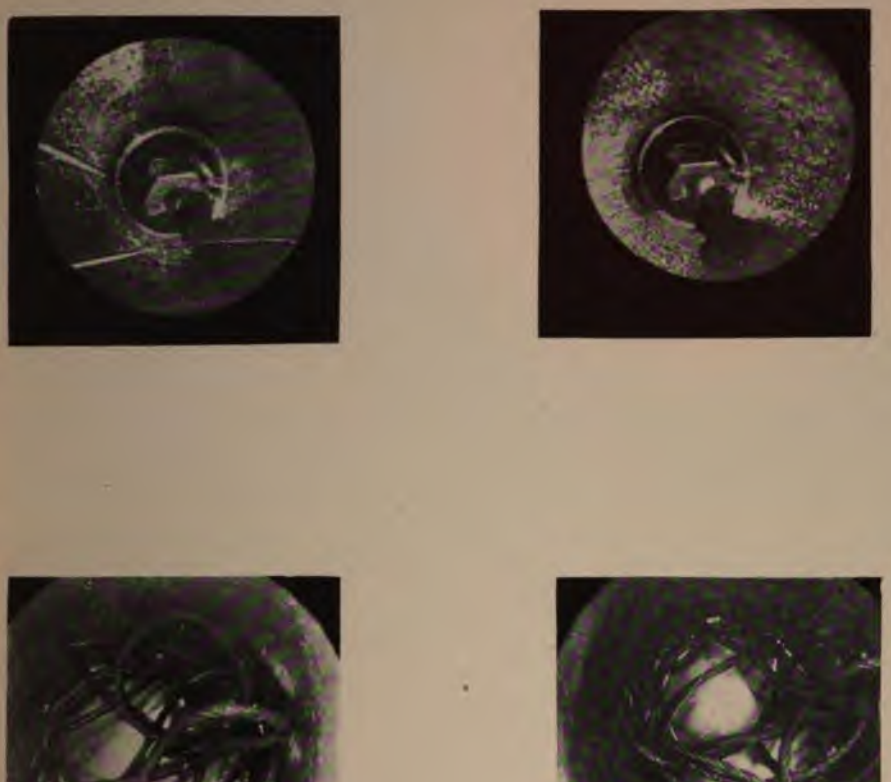

Fig. 39.—Photographs of Lost Articles in Baku Oil Wells.

best quality and without flaw, and should always, in difficult cases, employ instruments which can be disconnected simply and removed, if the lost tool refuses to stir. Failure to properly appreciate these elementary precautions leads to the loss of the fishing tools as well as the boring instruments, and a greatly aggravated operation for the recovery of both.

Lining the Well.—The nature of the strata in the Baku oil fields rarely admits the boring of many feet without lining tubes, and it is advisable, if accidents are to be avoided, never to allow more than 20 feet, or even 10 feet in some ground, of unprotected bore-hole. In some loose sands and very soft ground, boring is conducted without an under-reamer, and the tubes are kept almost level with the boring bit, but sometimes the tubes sink into the strata alone as the sand is removed by the sand-pumps. The peculiar nature of the Baku oil lands occasions much trouble in boring, especially in some old districts where the ground has been considerably loosened by the abstraction of oil and sand from numerous bailing wells, and the tubes can only be kept free by constant attention. Each time a new tube is added, the whole column must, with the aid of pulley-blocks, be raised and lowered a number of times if there is the least hesitation in its movement, and driving with a heavy monkey must only be resorted to when repeated attempts to free the tubes in the above manner have failed.

At times the liquid in the well suddenly sinks when a porous ground is met with, and under such circumstances there is much danger of the tubes stopping through falls of strata, resulting from the diminished internal pressure. If tubes become fixed after passing only 100–150 feet through cavings of strata, they may often be freed by pumping water into the well for a time, but this should only be allowed where there is no danger of flooding neighbouring wells. A sufficient guarantee of the impracticability of carrying one string of casing down to great depths is to be found in the average results of the very best and oldest boring contractors of Baku, who cannot show an average, with any system, exceeding 280 feet below the preceding shoe. A contract with a Baku boring contractor usually contains a clause stipulating that each column of tubes shall on an average pass 210 feet below the shoe of the former column.

A driving monkey will often make the tubes pass an obstacle when no direct pressure will produce any effect, so that before abandoning a column of tubes, driving should not be neglected. Driving must only be conducted with discretion, for the excessive vibration produced by the blows causes all the rivets to become loosened, and the tubes sometimes to bulge; indeed, it is an operation which should always be avoided, wherever possible, unless screwed casing is in use. A driving monkey may be constructed in many forms, but it generally consists of a heavy cast-iron block provided with guide-pieces, and is raised by means of a rope from the boring machine to a height of from 1 to 6 feet, and then allowed to fall of its own free weight. The top casing is fitted with a wrought-iron ring, which receives the force of the impact and prevents damage to the tubing.

Repairing Wells.—One of the most difficult operations connected with boring work is found in repairs to wells which have collapsed or become damaged through landslips, etc. Many feet of iron casing have often to be bored through and made to disappear in front of the tools, before a new column can be lowered and any progress be made. The usual method of cutting up casing is to ram the damaged part with hard stones, and produce a solid and even base, upon which the cutting edge of the bit may work without danger of becoming jambed or broken. The ramming with stones also assists the operation in another way, as the iron is often forced outwards into the walls of the boring, and thus reduces the amount of actual cutting needed to allow the next column of tubes to sink. It is really wonderful how long lengths of casing disappear in the Baku strata, often with very little work, and it is not uncommon to drive to one side and entirely lose sight of 100 feet of tubes ¼ inch thick. If a great deal of the iron has to be actually cut up into fragments and removed, as happens where the ground is too hard to allow expansion of the tube, special high-quality steel chisels must be employed, and the work of cutting up a few feet may occupy months.

Blasting with dynamite or nitroglycerin would do in a few seconds the work on which months and months are often spent; but there are strict laws and regulations limiting the use of explosives in Russia, and it is not easy to obtain the necessary permission for such work.

Contract Boring.—In America the practice is almost universal of employing contractors for boring oil wells, a system that is to be highly recommended, but one carried on only to a small extent in the Russian oil fields. Contractors, who make a specialty of boring, collect the most skilful artisans in the district, and keep them in their service engaged solely on one class of work, in which they become very expert, and gain an extensive knowledge of the local requirements, etc. Contractors of repute perfect their machinery and adapt it to the peculiar conditions existing in the area worked. They always keep in readiness a large collection of special and expensive fishing tools, and are thus able to send out at a moment's notice any fishing instrument needed to recover a lost boring tool.

Firms of slender means or moderate size are never provided with an outfit equal to that of a boring contractor. They have difficulty in securing and retaining the services of reliable men to carry out the work, and are usually handicapped by a scarcity of fishing tools and special instruments, which have to be hired at exorbitant prices. If the chief engineer of a company has to supervise the whole of the boring work, he is kept fully occupied by this department alone, and naturally other branches, just as important, have to suffer. Contract boring relieves the engineer of much work and anxiety, and gives him time to pay greater attention to the engineering problems of importance, and to the general management. Boring contractors also accept all responsibility for injury to workmen—a matter of no little importance in dangerous boring work—and have to replace, at their own expense, the loss or damage of tools and boring machines through fire, etc. In the majority of cases the rate of boring by good contractors greatly exceeds that of private companies, and nearly all the large firms who do not give out all their work, deliver over to contractors their deepest and most important wells.

During 1900 and 1901, when the boom in the oil trade was at its height, there was a great demand for contract boring masters, and their prices were increased, as a consequence, until a very high figure was reached; but prices have now fallen considerably, and the services of good men can be obtained for a moderate sum. Until recently, boring contractors were in such demand that they could not be persuaded to accept any well for repairs or deepening, an attitude which made it necessary to keep a boring staff and a stock of tools for this purpose alone; but to-day most contractors will willingly execute any work at a reasonable price. The cost per foot of self-bored wells seems, at first sight, to throw contract work into the shade entirely, but if due consideration is taken of the quantity of casing used, the finished diameter of the well, the maintenance of expensive workshops, and stocking of valuable tools, loss or damage of plant in fires, insurance of workmen, extra quarters for workmen, etc., the subject appears in a different light. The chief aim is *not* to complete a well at a small cost per foot, but to get a well producing in the shortest possible time, and a little study will prove how insignificant the former is to the latter in most places.

In the congested districts of the Balakhany-Saboontchy plateau, and latterly in the Bibi-Eibat oil field, each firm works in competition with its neighbour, and each uses its greatest exertions to get down to a prolific source first. The earliest arrival, if he bores well, secures the cream of the stratum, and, as a consequence, impoverishes his neighbour's plot by draining his oil ground almost as much as his own. The speed of boring is thus a very important matter, and many properties could be mentioned where the activity of one syndicate has robbed the adjoining sleepy or impecunious property-holder of millions of poods of oil, and reduced the value of the plot to a fraction of its original worth. Rapid boring obviously brings about an earlier return for the expenditure, and, indeed, the output from a single well may in a few months entirely repay the initial cost, thus setting capital free to conduct further exploitation.

Another important feature connected with contract boring is that the contractor engages to complete the well at a specified depth with a prearranged diameter of casing (or bore another well at his own expense), which is a size that in all cases permits deepening. Boring contractors not only fulfil this clause, but they generally complete the well with a much larger diameter, and use a smaller quantity of casing than is estimated for.*

The terms of a boring contractor in the Baku district are, roughly, as follows: The company supplies the contractor with a derrick, wooden shaft, steam-engine or motor of requisite power, electric light, roadway to the well, foundations for boring machine, and all water required during the work for the purpose of the well. The company also provides and conveys to the well all lining tubes in couples or singly, as required, and keeps the contractor supplied with these in sufficient quantities to prevent any stoppage. The company must also give to the contractor all materials required for cementing the well, if this is needful, and supply the necessary tools for cutting out and removing the tubes, if this is advisable or instructed.

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* When a column of tubes cannot be induced to proceed deeper, the boring has to be continued with a diminished size of lining tubes. When good contractors are employed, the boring work progresses faster, and the tubes are kept more frequently in motion; consequently each column is made to pass a further distance than in slow boring, and a less number of columns of tubes is required.

The contractor, on his side, undertakes to commence the well with a 28-inch or 30-inch column, and continue uninterruptedly day and night, except on holidays prescribed by law, until oil is found in sufficient quantities to justify the company taking over the well. The contractor further undertakes that each column shall, on an average, pass 30 sagenes below the shoe of the preceding column, and if a depth of 200 sagenes is not reached with a 14-inch column, he must supply additional columns at his own expense. All stoppage for trial bailing or other cause, authorized by the company, and resulting in the failure of the column thus stopped, or the subsequent column, passing 30 sagenes, relieves the contractor of the obligation under this head. Damage of casing or collapse, resulting from such trial bailing, the company is held responsible for, but the contractor will endeavour to put the tubes in order and proceed deeper quickly. Perhaps it should be explained here that a trial bailing generally has the effect of drawing in sand and other material, which have accumulated around the casing to such an extent that, although the tubes may have been quite free previously, they cannot be induced to move again. The effect of a trial bailing is not always confined to the single column of casing, for the loosening of the strata, as a result of the bailing, causes a constantly rising plug to appear, which may take months and months to clear, and even cause subsequent columns of tubes to stick fast, after passing but a few feet below the preceding shoe. This plug-forming is very prevalent in some districts of the Baku oil fields, and its occurrence can only be prevented by leaving the strata undisturbed as much as possible, *i.e.*, by not removing liquid from the well, and, instead of using suction pumps and bailers for cleaning out the detritus, employ only augers. If at any depth the well is ruined or damaged to such an extent, through some fault of the contractor, that it cannot be repaired, then he undertakes to bore a new well to the depth of the old one, lined with tubes of equal quality supplied at his own expense; but he reserves the right to recover any casing he can from the abandoned well.

For each sagene bored, the contractor receives 80 roubles, to a depth of 100 sagenes; from 100 to 110 sagenes, 90 roubles a sagene; and for every increase in depth of 10 sagenes to a depth of 200 sagenes, the price increases by 10 roubles a sagene. From 200 sagenes the price increases by 20 roubles a sagene every 10 sagenes. The contractor accepts all criminal and civil responsibility for accidents or injuries to workmen, and agrees to fulfil all demands made by the local authorities for this class of work. The contractor will also keep a correct journal of the boring operations, and undertakes to carry out with his own tools any special instructions given by the company to shut off water, or perform other unforeseen work. For all special work not specified in the contract as obligatory, such as trial bailing, cleaning plug afterwards, cutting out tubes for cementing, or other purposes, lowering protective column, or any succeeding one lowered at the company's request, repairing damage resulting from trial bailing, etc., the company pays the contractor 30 roubles a day. Any stoppage of work caused by the company not supplying the necessary accessories, must be paid for at the same rate, and *vice versâ*, if the contractor ceases work through no fault of the company, he must pay a penalty of 30 roubles a day during such delay. The payment of accounts for work executed must be settled in cash not later than the 10th inst. for the work done during the preceding month.

TABLE XIV.

For estimating Cost of Contract Boring Work.

Giving price per sagene at different depths at usual rate of increase—10 roubles per sagene every 10 sagenes up to 200 sagenes, and 20 roubles per sagene every 10 sagenes afterwards—with starting prices from 60 roubles to 90 roubles per sagene.

Depth in sagenes.	Cost per sagene (in roubles), commencing with different prices.						
	60.	65.	70.	75.	80.	85.	90.
0 to 100	60	65	70	75	80	85	90
100 „ 110	70	75	80	85	90	95	100
110 „ 120	80	85	90	95	100	105	110
120 „ 130	90	95	100	105	110	115	120
130 „ 140	100	105	110	115	120	125	130
140 „ 150	110	115	120	125	130	135	140
150 „ 160	120	125	130	135	140	145	150
160 „ 170	130	135	140	145	150	155	160
170 „ 180	140	145	150	155	160	165	170
180 „ 190	150	155	160	165	170	175	180
190 „ 200	160	165	170	175	180	185	190
200 „ 210	180	185	190	195	200	205	210
210 „ 220	200	205	210	215	220	225	230
220 „ 230	220	225	230	235	240	245	250
230 „ 240	240	245	250	255	260	265	270
240 „ 250	260	265	270	275	280	285	290

It will be seen that a contract-bored well, carried out in accordance with the terms of a contract commencing at 70 roubles a sagene (prices of good contractors range from a starting price of 60 roubles to 90 roubles a sagene), will cost, lined with ¼-inch casing to a depth of 200 sagenes, 40,000 roubles.* The cost of extra work, such as cementing, trial bailing, cutting out and removing casing, is almost repaid, in most cases, by the recovery of a large portion of the tubes, which may, with slight repairs, be prepared for another well. The details of the above estimate are as follows:—

Estimated Cost of Well, 200 Sagenes Deep, by Contract.

Boring.

0 to 100	sagenes at	70	roubles	per sagene	=	7,000	roubles
100 „ 110	„	80	„	„	=	800	„
110 „ 120	„	90	„	„	=	900	„
120 „ 130	„	100	„	„	=	1,000	„
130 „ 140	„	110	„	„	=	1,100	„
140 „ 150	„	120	„	„	=	1,200	„
150 „ 160	„	130	„	„	=	1,300	„
160 „ 170	„	140	„	„	=	1,400	„
170 „ 180	„	150	„	„	=	1,500	„
180 „ 190	„	160	„	„	=	1,600	„
190 „ 200	„	170	„	„	=	1,700	„
						19,500	„

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* This price is, of course, exclusive of electric light, power, etc., which the company provides.

Casing.

Inches.							
28 × ¼.	10	sagenes at	17·5	poods per sagene	=	175	poods
26 × ¼.	40	,,	16·2	,, ,,	=	648	,,
24 × ¼.	70	,,	14·8	,, ,,	=	1,036	,,
22 × ¼.	110	,,	13·8	,, ,,	=	1,518	,,
20 × ¼.	140	,,	12·6	,, ,,	=	1,764	,,
18 × ¼.	170	,,	11·4	,, ,,	=	1,938	,,
16 × ¼.	200	,,	10·2	,, ,,	=	2,040	,,
14 × ¼.	200	,,	9·0	,, ,,	=	1,800	,,
	940					10,919	,,

10,919 poods of iron at 1·50 rouble = 16,378 roubles
940 sagenes of tubes at 5 roubles = 4,700 ,,
21,078 ,,

If the well is cemented twice, once between the 28-inch and 22-inch casing, and again between the 22-inch and 16-inch, and the 14-inch column is simply left as a protective column, then the following tubes may be recovered:—

Inches.					
26 × ¼.	5	sagenes	=	81	poods
24 × ¼.	35	,,	=	518	,,
20 × ¼.	105	,,	=	1323	,,
18 × ¼.	135	,,	=	1539	,,
	280	,,	=	3461	,,

280 sagenes of tubes at 5 roubles = 1400 roubles
3461 poods of iron at 1·50 rouble = 5191 ,,
6591 ,,

If 50 per cent. for depreciation be deducted from the value of the recovered tubes, the well may be credited with 3295 roubles, which sum will, in some cases, repay the extra work done.

The above figures are given with a maximum quantity of casing; but a good contractor generally completes a well with a much smaller quantity of tubes, and will reach 200 sagenes with an 18-inch or 20-inch column of tubes.

The saving in casing alone is great where first-class contractors are employed, and numerous examples could be quoted where years have been taken to complete a single well by a cheap contractor, or a private ill-provided firm.

Use of Dynamite in Wells.—Until 1902 permission was never granted by the authorities to use violent explosives in the wells, but in this year the necessary permit was obtained to make use of dynamite in several bore-holes of the European Petroleum Co. Explosives are particularly useful in repair work, as will doubtless have been gathered from parts of this chapter, for in the space of a few seconds more destruction may be wrought to damaged casing or irrecoverable tools, etc., than in months of boring with steel chisels. For the purpose of fracturing a number of tubes and opening a higher oil source much benefit is derived from the use of explosives; indeed, in many cases this is the only method of performing such work.

Nitroglycerin is the explosive generally used in America for blasting work, but it is exceedingly dangerous, and in Baku its use has been confined to the safer form known as dynamite, which contains from 50 to 70 per cent. of nitroglycerin. As the value of dynamite is destroyed by contact with water, it is necessary to construct a strong vessel for its reception where the explosion has to be conducted under a great depth of water. In deep wells, when the depth of water is very great, the torpedo or vessel in which the dynamite is inserted, must be capable of withstanding a pressure of 500 lbs. per square inch, or even more, so that a very powerful case is essential. The vessel should be provided with a lid that can be simply removed and replaced, in order that the torpedo may be lowered into the well prior to filling with dynamite, and tested as to its water-tightness everywhere. No special instructions are needed for the construction of a suitable torpedo, and reference to the illustration (Fig. 40), which represents a 30-lb. torpedo being

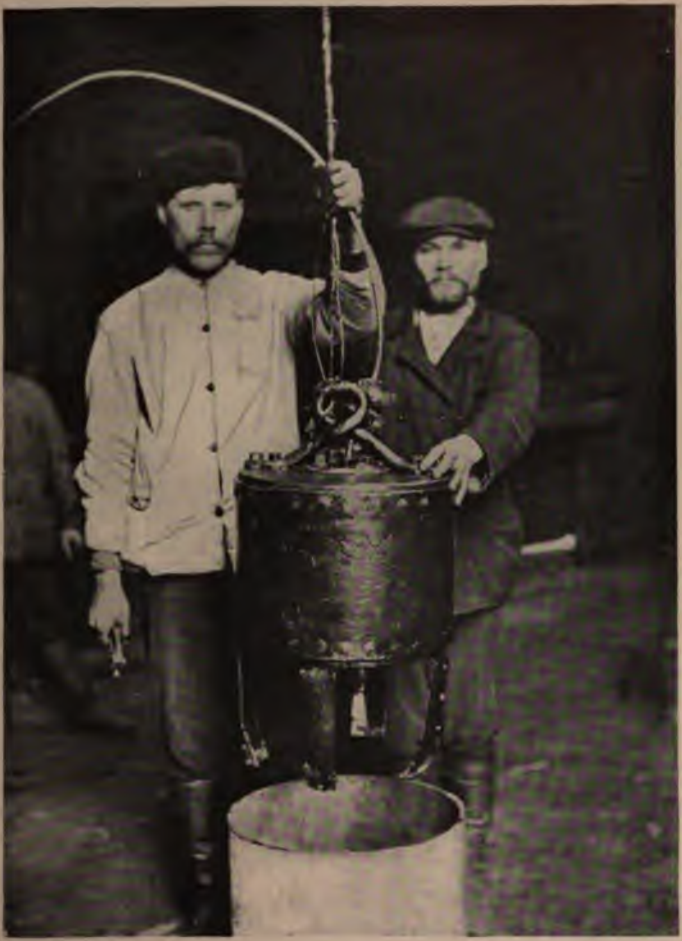

Fig. 40.—Torpedo with 30 lbs. of Dynamite being lowered into a Baku Oil Well.

lowered into a Baku oil well with everything in readiness for firing on reaching its destination, will show the manner in which a suitable chamber may be manufactured. Firing may be conducted either by a timed fuse or electrical connections, the end of the fuse, or the extremities of the electric wires, as the case may be, being inserted in a percussion cap which is introduced into a piece of dynamite. A suitable device must be arranged for admittance of the fuse or electric wire so that water cannot leak past; but the difficulty can be overcome by the affixture of either a gland with a stuffing box, or an arrangement that permits of soldering at the point of passage through the cover.

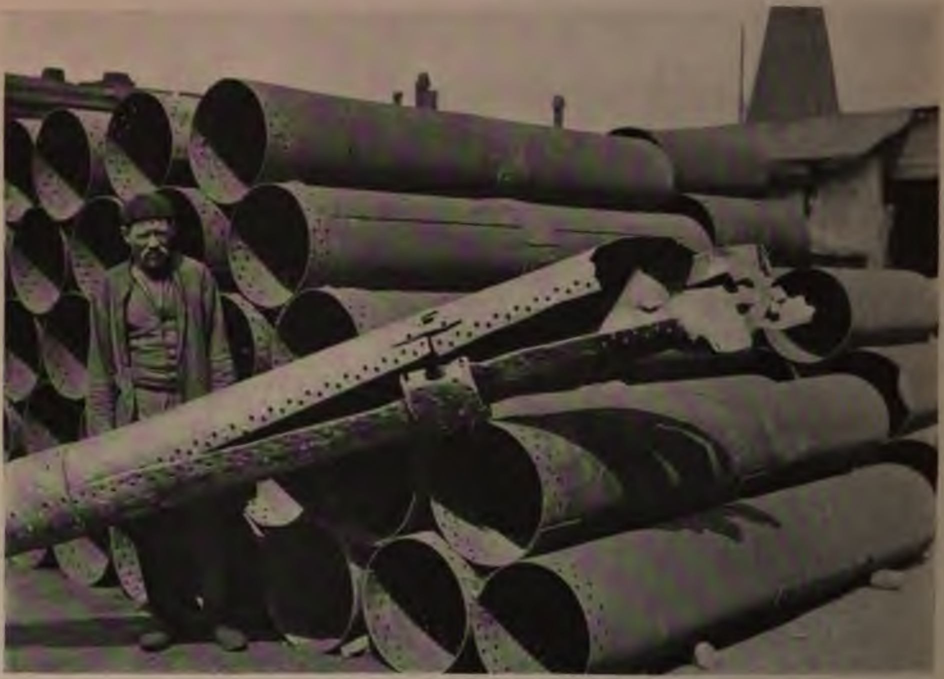

Fig. 41.—Tube removed from an Oil Well after Explosion of 20 lbs. of Dynamite.

When electrically firing a charge (the electric light cable is generally used), an insulated cable must be attached to the suspension rope, but a return wire is superfluous, as the rope itself may be made to serve the purpose.

The Baku strata are generally so soft and spongy that large charges of dynamite are needed to produce any damaging effect upon the casing, and in practice it has been found advisable to use 30 to 40 lbs. in wells of large diameter, and even then there are no surface indications of the explosion, the whole of the gases apparently finding relief in the ground.

Fig. 41 shows a tube drawn from a Baku well after the explosion of 20 lbs. of dynamite, from which an excellent idea is obtainable of the extent of the damage the tubes sustain.

CHAPTER VI.

WELL CASING.

Well Casing.—Special class of lining tubes for Russian wells—Comparison of early, later, and present casings—Manufacture of tubes—Successive improvements—Distinguishing characteristics of a modern tube.

Length of the Tubes.—Practical reasons for adoption of standard length—Practice of decreasing upwards the thickness of tubes in a column.

Quality of Iron for Well Casing.—Conditions determining qualities desirable.

Butt-jointed Tubes.—Point of weakness in lap-jointed tubes—Description of one example of butt-jointed tube—Drawback—Double tubes—Method of construction.

Method of Manufacture of Riveted Casing.—Modern practice of employing contractors with special tools and machinery—Gauges—Method of setting out rivet-holes—Punching the rivet-holes—Countersinking the holes—Bending the tubes—Facing up the edges of tubes—Caulking and completion.

Pneumatic Riveters and Caulkers.—Attempts to introduce them.

Sizes and Weights of Iron for Tubes.—Useful tables for estimation of weights and sizes of iron for different diameters of casing.

Jointless Tubes.—Theoretical advantages—Practical non-success hitherto—Their probable future.

Riveting the Tubes in the Well.—Description of riveting machine, and mode of employing it.

Screwed Casing.—Success of this form in America, and failure in the Baku oil territory—Some success also at Grosny, where geological conditions approach those of America—Militating conditions at Baku—Some failures undoubtedly due to defects in tubes—Conditions to be entered in specification in ordering screwed tubes for Baku, to avoid thread-stripping and breaking away of screwed part.

Tube Clamps.—Description and use.

Raising Lost Tubes.—Necessity for serious attempts to raise—Tube-raiser, procedure, and danger in use.

Tube-cutters.—Construction and use.

Removing Casing.

Repairing Bulged Casing.—Causes making repairs necessary—Description and use of "expander" or "drift."

Advantages of Different Classes of Tubes.—Conflicting views of experts—Cases in which no variety of tube could resist fracture—Local conditions should decide.

Protective or Preservative Columns.—Opinions divided as to their value—Circumstances in which their value is undeniable.

CHAPTER VI.

WELL CASING.

Well Casing.—The large diameter of most of the Russian wells, rendered advisable by the usual manner in which the petroleum is extracted, has led to the manufacture of a special class of lining tubes or casing, for it is quite apparent that screwed casing, apart from its expense, is unsuitable for such sizes as 20 to 30 inches diameter, but even where small diameters are reached, the excessive prices demanded for English or American screwed tubes, which can be profitably imported in competition with those of Russian make, notwithstanding the heavy import duty, strictly limits their employment. In the early days of the Russian oil industry, when only small and shallow wells had to be bored to obtain oil in prodigious quantities, a simple form of riveted lining casing was forced upon the local oil producers by the isolation of Baku from the outer world, through the absence of railway communication; but since the opening of the Trans-Caucasian Railway to Batoum, and the Vladikavkas Railway to Novorossisk, the transport difficulties have been removed, and screwed tubes for wells of small diameter are coming more generally into use. The early well casings were constructed from $\frac{1}{8}$-inch sheet iron, and their manufacture was not given much attention, but as it became necessary to go deeper and deeper to reach oil, the producers directed their abilities to the formation of a stronger form of casing, with the result that, although the original design was exclusively retained, the thickness of the iron was increased to $\frac{1}{4}$ inch and $\frac{5}{16}$ inch, and other important changes were initiated with success. As the oil wells became larger and deeper, and the manufacture of casing a department annually increasing in importance, power-driven machinery of improved design gradually superseded the antiquated hand types found in the tube works, and much ingenuity was displayed in the improvement of the quality and cheapening of production. The usual form of tube manufactured on the Russian oil fields is shown in the illustration, from which its construction will be clearly understood (see Fig. 42).

Rectangular sheets of iron, cut to the requisite dimensions after due allowance for lap, are rolled into a circular shape, and riveted along the lapped joint with single, double, or treble rows of rivets, placed zigzag; a collar or socket being formed by riveting to one extremity of each tube a rolled strip of iron, into which the free end of a similar tube may slip. The collars, which formerly rarely exceeded 7 inches in depth, have been increased of late years to 9, 12, 14, and even 18 inches in special cases, and the lap joint of the casing, which was previously a very weak spot, has been strengthened by double and treble rows of rivets, instead of relying upon a single row that was exposed to the influence of injurious compounds in the well waters, and often became oxidized to such an extent that a collapse followed. The point of junction between two successive tubes was, until the last few years, entirely neglected, the rough sheared edges of the plates being permitted to butt together, or rather to lie, in most cases, separated by a small space, with the result that, on the application of a number of blows from a driving monkey, most of the rivets were shaken loose, and many of them fractured entirely. As the use of a driving monkey cannot always be avoided in boring, every proprietor can well afford to spend an extra sum in assuring better contact between successive tubes, for not only are the tubes themselves weakened by the loss of the rivets, but a pathway is opened for the admission of water into the well, and the difficulties of cementing are increased.

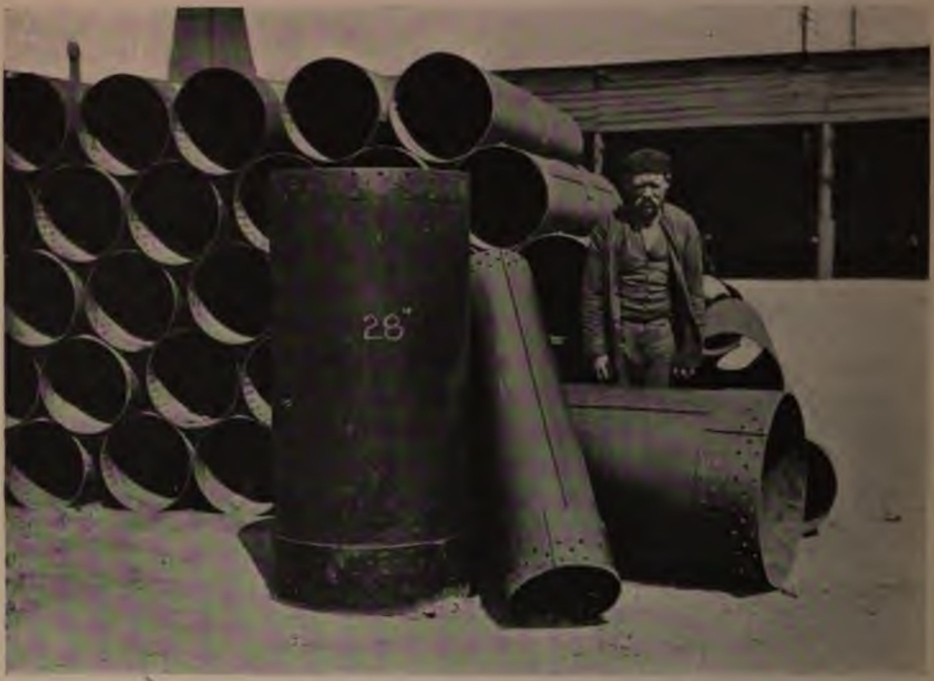

Fig. 42.—Riveted Well Casing as used in the Russian Oil Fields.

Most large firms have now taken measures for assuring perfect contact at this point by facing up the ends of the tubes, and in all modern, well-equipped tube works on the oil fields, a tube-facer will be found specially designed for so treating the casing. A proper facing lathe designed for this particular purpose, will, by simple alteration of the bolting-down attachment, take all sizes of tubes from 10 inches to 22 inches in diameter, and 2 arsheens (4 feet 8 inches) to 7 feet long. The facing is conducted at both ends simultaneously, and each head-stock is fitted with double slide-rests and tool-holders, to which the feed is automatically applied by a star-wheel attached to the spindle actuating the revolving slides.

The following characteristics distinguish a tube of most modern construction:—

(1) Thickness of iron not less than $\frac{1}{4}$ inch.
(2) Collars not less than 9 inches deep.
(3) Double or treble riveted lap joint.
(4) Faced edges.

Length of the Tubes.—The standard length of a single tube in the oil fields is 2 arsheens (4 feet 8 inches), as this has been found in practice to satisfy the requirements of boring without being too unwieldy to arrange for and manipulate. Longer tubes have been made by one Baku firm, at least, on a large scale, but the practice has not been generally adopted on account of some practical objections to their use, notwithstanding the important saving that may be effected both in the cost of manufacture and in the time of lowering. In the first place, it is maintained that the collars are a source of strength to the tube, and that too long a distance between successive collars exposes the casing to the danger of collapse; and in the second place, it is insisted and especially emphasized by the boring experts, that where the collars are separated by a long distance the freedom of the column of tubes is endangered by falls of earth around, which tend to arrest their passage. Where collars follow in rapid succession the under-reamed bore-hole is kept throughout of a diameter equal to the extreme dimensions of the sockets, which, indeed, act in themselves as cutters, but if long distances are allowed to intervene between successive collars, there is a greater chance of falls of ground or cavings collecting around the tubing between the collars that cannot be cleared away when the column is put in motion for lowering. Experience has taught that in many districts a length of 2 arsheens is the most convenient distance to lower after the completion of one piece of boring, and this fact has, doubtless, to some extent influenced the retention of the old 2-arsheen tubes. All these objections could, however, be overcome, and longer 1-sagene tubes used if the lower portion of the column, which is destined to be buried in the ground, were made of 2-arsheen tubes, and the remainder completed with sagene tubes, and provision was made in the shaft for manipulating the sinking of the column at will. When soft flowing ground is encountered it is often found necessary to keep the tubes close to the boring bit, to facilitate which 1-arsheen (2 feet 4 inches) tubes are added as the work progresses.

When lowering a new column of casing in a well, the tubes are generally connected in twos or fours at the tube works, and supplied to the well consequently in lengths of 4 arsheens (9 feet 4 inches) or 8 arsheens (18 feet 8 inches), thus considerably hastening the process of sinking the column to the shoe of the preceding string. Some engineers favour the practice of forming a single column of casing of several thicknesses of iron, having about one-third of the column composed of $\frac{5}{16}$-inch iron at the bottom, the middle third of $\frac{1}{4}$-inch iron, and the top third of $\frac{3}{16}$-inch iron, as by this means the stronger tubes are left in the portion of the well needing the greatest support; but it is in reality more recommendable to carry $\frac{1}{4}$-inch tubes entirely to the surface, for they allow much more manipulation if the column "hangs" during boring, or needs raising at some future time.

Quality of Iron for Well Casing.—The quality of iron best suited for well casing is a subject requiring some consideration, for in order to resist the somewhat rough treatment it receives in working up, a kind of iron is needed which must not be sufficiently soft to be forced out of shape by a slight side-thrust, nor brittle enough to suffer damage from the hammering it receives when the mouth of the collar is expanded to admit freely the next tube; a hard medium quality has been found to answer the purpose well. Russian iron that costs in Baku (1902) about 1 rouble 50 copecks a pood, or about £9 10*s.* a ton, is generally employed for the manufacture of casing; but new deliveries should always be subjected to a scrutinizing inspection, to ascertain that the sheets are free from scabs, that are often found, and if passed unnoticed may be responsible for extensive damage afterwards in the wells. For the sake of an extra few copecks a pood in price, common quality iron should not be purchased, for not only do the tubes sometimes bulge during boring when the iron is soft, but cheap brittle iron breaks up when the rivets are driven out during the removal of a column, and the tubes have to undergo expensive repairs before they can be used again.

The sheets of iron are usually ordered from the manufacturers, or their agents, cut to the correct dimensions for the various sizes of tubes; for as such enormous consignments of these sizes are used on the oil fields, they are nearly always stocked in large quantities ready for delivery.

Butt-jointed Tubes.—The principle of the lap-jointed tube is not compatible with the greatest strength to resist a lateral pressure, and as occasional collapses through fracture of the rivets or splitting of the rivet-holes bring this point prominently to notice, several attempts have been made to introduce a class of tubes possessing a butting joint. In one example, the iron plates were planed along their edges, and after being rolled and the faced edges made to butt, a narrow connecting strip was riveted along the joint to the position of the collar at each end. Endless welded collars were inserted on one end of the tubes and riveted on, after which the whole of the joints were carefully caulked on the outside seams and round the collars. A very serviceable and strong class of casing was in this way formed; but in this particular instance the collars, which were supposed to be drilled accurately to gauge, were far from true, and it was impossible to connect two tubes neatly or securely together on account of the rivet-holes not corresponding. The principle, however, is good, and if only a little perseverance were used, the initial difficulties could be removed and an improved type of lining tube could be produced.

Double Tubes.—Another introduction, brought forward with the object of producing a stronger type of casing, is the double tube, which is practically an ordinary tube with a collar equal in length to the tube itself, the projection of one sleeve beyond the other forming the collar into which the next tube is placed. A double tube is, as will be gathered from the description, simply a combination of two lap-jointed tubes of equal length, one of which encircles the other, but projects some 7 to 9 inches beyond to form the collar. The two sleeves are riveted together along their lengths and caulked in the ordinary manner before delivery to the well, where on lowering they form a flush-jointed column.

Method of manufacturing Riveted Casing.—Many Baku firms have their lining tubes made by outside contractors, who are supplied with the necessary materials, and have to deliver the finished casing to the wells; but most large producing companies now own their own tube works, which are furnished with power-driven punches, rolls, and drilling machines, in place of the old hand types that are still largely in use in the smaller shops. The sheets of iron, after inspection and weighing, are cut in a shearing machine to the correct size, if not supplied in that form, and after being flattened out perfectly level by hammering with wooden mallets on an iron slab, they are passed on to the marker-out, who sets out the holes from a gauge previously prepared.

Gauges.—Every tube works should be provided with a reliable set of gauges, accurately prepared from sheets of $\frac{5}{16}$-inch or $\frac{3}{8}$-inch iron, planed up perfectly true on their edges, made perfectly rectangular, and the holes drilled to a minute degree of precision. A complete set should be prepared for all sizes of tubes and collars from 8 inches to 30 inches, all of which should be clearly figured, and stored in a rack where they cannot be damaged or knocked out of true by careless blows. The gauges are clamped to the iron plates by small screw-clamps, and the holes are either scratched through with a sharp scriber, or dotted through with a centre-punch which must accurately fit the drilled holes, and make an impression exactly central; but it is advisable that the scribing be always insisted on, and the line dotted in with small centre-dots, so that a record remains of the accuracy of the punching.

Punching the Rivet-holes.—The set-out sheets are placed on trolleys, and removed to the punching machines, where the scribed holes are punched. In the case of very wide collars being used, or double tubes, when the holes extend to a distance of 16 to 18 inches from the edge of the plate, special punching machines are needed with a gap 18 inches deep, but in other respects the punches may be of the ordinary belt-driven type. The punching must be accurately performed, or great difficulties will be subsequently met with in riveting up the casing in the well, and it is on account of this danger that it is better to insist upon the holes being marked with a scriber and dotted, than to rely upon the workman's guidance from a single dot, leaving no easily-seen trace of careless work.

Countersinking the Holes.—From the punching machines the sheets are conveyed to drills of the "sensitive" type, operated by a long hand-lever, where the holes are countersunk on the burred side, which is destined to be the inside of the tube, sufficiently to admit the head of the rivet. The drilling machines must be provided with a clear space of 18 inches between the stand or frame and the drill-spindle, and must be fitted with a table large enough to receive the largest plates. Wall drills may be conveniently used for the work, and a wooden table of a temporary nature may be constructed beneath the drill, to contain the sheets of iron, part of which may be movable and supported on trestles. The plates are often caused to rest upon a number of cast-iron balls, which permit the movement of the sheets with freedom from hole to hole by a single attendant.

Bending the Tubes.—The punched and countersunk sheets are then transferred to the bending rolls, which are generally power-driven, and arranged with gearing to give them a backward-and-forward motion, where the plates are rolled into a circular tube. In one case under observation, the tubes were formerly bent in a hand machine, where three men, working laboriously, could only turn out forty tubes a day, but after a little practice the same men could with ease bend 120 tubes a day with power-driven rolls. The tubes are then passed on to the riveters, who place the tube upon steel rails supported at one end, and rivet the lap joint, countersunk-headed rivets being inserted from the under side and hammered cold into a small head on the outside. The end three or four holes must be left unriveted, as the collars have subsequently to be attached, but a temporary bolt is put into the last hole at each end to prevent the edges from opening in the next operation, namely, facing up the ends.

Facing up the Edges of the Tubes.—The facing of the edges is done in the machine already described, but before commencing to face up a certain size of tube, the holding-down device must be carefully set to ensure the whole of the tubes being faced perfectly true. One cut across with the four tools should suffice to complete the operation, which scarcely occupies more than a few minutes when the machine is once set for a particular size.

Caulking and Completion.—The tube is then returned to the riveters, who connect the collar to one end, and then pass it along to the caulkers, who caulk the seam of the lap joint and around the junction of the collar. The tube is then complete, and is ready for lowering into the well.

Pneumatic Riveters and Caulkers.—Pneumatic riveters and caulkers have been introduced successfully during the last year or two for the manufacture of casing, and have assisted in the more rapid, improved, and cheapened production of lining tubes. Both riveters and caulkers have reached a perfected state, and a tool can be operated by a single workman, the compressed air being supplied by compressors, and conducted by a flexible tube from the air main to the operator. Like all innovations, the introduction of these new tools met with much opposition, the men complaining of the effect of the vibration on their health.

Sizes and Weights of Iron for Tubes.—Table XV. gives full particulars of 8-inch to 30-inch riveted lining tubes, 2 arsheens (56 inches) long with 9-inch collars, made from $\frac{3}{16}$-inch, $\frac{1}{4}$-inch, and $\frac{5}{16}$-inch iron; and Table XVI. gives the same details for lining tubes with 12-inch collars. The last column simplifies the estimation of the weight of a column of tubes in a well.

TABLE XV.

FULL PARTICULARS OF LINING TUBES WITH 9-INCH COLLARS.

Diam. of tube.	Size of iron for tube.	Size of iron for collar.	Tube. Weight in poods.			Collar. Weight in poods.			Total weight in poods.			Total weight in poods per sagene.		
			$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.
Ins.	Inches.	Inches.												
8	56 × 29	9 × 32	2·3	3·1	3·9	0·41	0·55	0·68	2·7	3·6	4·6	4·0	5·4	6·9
10	56 × 35	9 × 38	2·9	3·7	4·7	0·49	0·66	0·83	3·4	4·3	5·5	5·1	6·4	8·2
12	56 × 42	9 × 44	3·4	4·5	5·7	0·57	0·76	0·95	4·0	5·2	6·6	6·0	7·8	9·9
14	56 × 48	9 × 51	3·9	5·2	6·5	0·66	0·88	1·10	4·6	6·0	7·6	6·9	9·0	11·4
16	56 × 54	9 × 57	4·4	5·8	7·3	0·74	0·99	1·2	5·1	6·8	8·5	7·6	10·2	12·7
18	56 × 60	9 × 63	4·9	6·5	8·1	0·82	1·1	1·4	5·7	7·6	9·5	8·5	11·4	14·2
20	56 × 67	9 × 70	5·4	7·2	9·0	0·90	1·2	1·5	6·3	8·4	10·5	9·4	12·6	15·7
22	56 × 73	9 × 76	5·9	7·9	9·8	0·97	1·3	1·6	6·9	9·2	11·4	10·3	13·8	17·1
24	56 × 79	9 × 83	6·4	8·5	10·7	1·08	1·4	1·8	7·5	9·9	12·5	11·2	14·8	18·7
26	56 × 86	9 × 89	7·0	9·3	11·6	1·15	1·5	1·9	8·1	10·8	13·5	12·1	16·2	20·2
28	56 × 92	9 × 95	7·4	10·0	12·4	1·24	1·7	2·1	8·6	11·7	14·5	12·9	17·5	21·7
30	56 × 98	9 × 101	7·9	10·6	13·2	1·31	1·8	2·2	9·2	12·4	15·4	13·8	18·6	23·1

TABLE XVI.

FULL PARTICULARS OF LINING TUBES WITH 12-INCH COLLARS.

Diam. of tube.	Size of iron for tube.	Size of iron for collar.	Tube. Weight in poods.			Collar. Weight in poods.			Total weight in poods.			Total weight in poods per sagene.		
			$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.	$\frac{3}{16}$ in.	$\frac{1}{4}$ in.	$\frac{5}{16}$ in.
Ins.	Inches.	Inches.												
8	56 × 29	12 × 32	2·3	3·1	3·9	0·55	0·73	0·91	2·9	3·8	4·9	4·3	5·7	7·3
10	56 × 35	12 × 38	2·9	3·7	4·7	0·65	0·88	1·10	3·6	4·6	5·8	5·4	6·9	8·7
12	56 × 42	12 × 44	3·4	4·5	5·7	0·76	1·01	1·26	4·2	5·5	7·0	6·3	8·2	10·5
14	56 × 48	12 × 51	3·9	5·2	6·5	0·88	1·17	1·43	4·8	6·4	7·9	7·2	9·6	11·8
16	56 × 54	12 × 57	4·4	5·8	7·3	0·99	1·32	1·65	5·4	7·1	9·0	8·1	10·6	13·5
18	56 × 60	12 × 63	4·9	6·5	8·1	1·09	1·50	1·84	6·0	8·0	9·9	9·0	12·0	14·8
20	56 × 67	12 × 70	5·4	7·2	9·0	1·20	1·60	2·0	6·6	8·8	11·0	9·9	13·2	16·5
22	56 × 73	12 × 76	5·9	7·9	9·8	1·29	1·70	2·1	7·2	9·6	11·9	10·8	14·4	17·8
24	56 × 79	12 × 83	6·4	8·5	10·7	1·44	1·90	2·4	7·8	10·4	13·1	11·7	15·6	19·6
26	56 × 86	12 × 89	7·0	9·3	11·6	1·53	2·00	2·6	8·5	11·3	14·1	12·7	16·9	21·1
28	56 × 92	12 × 95	7·4	10·0	12·4	1·65	2·2	2·8	9·0	12·2	15·2	13·5	18·3	22·8
30	56 × 98	12 × 101	7·9	10·6	13·2	1·74	2·4	2·9	9·6	13·0	16·1	14·4	19·5	24·1

Table XVII. gives the same data as the foregoing tables for the usual sizes of double tubes from both $\frac{3}{16}$-inch and $\frac{1}{4}$-inch iron.

TABLE XVII.

PARTICULARS OF DOUBLE TUBES.

(All weights in poods.)

Diam. of tube.	Size of iron for outside tube.	Size of iron for inside tube.	Weight of outside tube.		Weight of inside tube.		Total weight.		Weight per sagene.	
			3/16 in.	1/4 in.	3/16 in.	1/4 in.	3/16 in.	1/4 in.	3/16 in.	1/4 in.
Ins.	Inches.	Inches.								
12	56 × 43	56 × 41	3·5	4·6	3·3	4·4	6·8	9·0	10·2	13·5
14	56 × 49	56 × 47	4·0	5·3	3·8	5·1	7·8	10·4	11·7	15·6
16	56 × 55	56 × 53	4·5	5·9	4·3	5·7	8·8	11·6	13·2	17·4
18	56 × 61	56 × 59	5·0	6·6	4·8	6·4	9·8	13·0	14·7	19·5
20	56 × 68	56 × 66	5·5	7·3	5·3	7·1	10·8	14·4	16·2	21·6
22	56 × 74	56 × 72	6·0	8·0	5·8	7·8	11·8	15·8	17·7	23·7

Jointless Tubes.—Several attempts have been made to produce a jointless tube, and only a few years ago one Russian firm contracted to supply welded tubes for boring purposes, and a large consignment reached the Baku oil fields. Theoretically the construction was ideal in nature, as one of the most defective features of the common casing was overcome; but in practice they exhibited none of the high qualities claimed for them, and a series of disasters followed their employment. The welding had apparently been very imperfectly executed, and when even moderate driving was resorted to they gave way, and collapsed beneath the pressure. Other trials have from time to time been made to produce a more perfect weld, but as no such tubes are now to be found in use, the experiments have presumably failed, or at least have not met with conspicuous success. The enormous developments in electricity naturally aroused the question of electrical welding, which is reported to produce an excellent contact, and several syndicates of importance have paid some attention to this interesting subject. So far no signal success has attended the experiments which would justify its adoption, but it is highly probable that within the next few years welded tubes will be extensively manufactured, in which case collars might be entirely avoided, and the end of the tube slightly enlarged to receive the next column.

Riveting the Tubes in the Well.—The necessity of riveting the tubes when placed in position in the well calls for some special appliance whereby they may be connected securely and without danger before lowering. Such an apparatus is locally termed a "riveting machine," and the details and method of its employment are shown in Figures 43 and 47.

Suspended by rods from a stiff cross-bar lying across the top of the tube are two hard cast-iron blocks, tapered on the inner side and provided with grooves which correspond with similar grooves planed on a wedge-block separating them, but rounded on the outer side to an arc equal to that of the tube to be riveted. A centre spindle, which is connected with and revolves freely in the wedge-block, and is provided with a square thread working in a brass nut on the cross-bar, when rotated by a wrench fitting on its square head, draws up the wedge-piece and forces the radial blocks outwards towards the tube. The two expanding radial pieces are deep enough to take the half of the widest collar used, and each occupies a sector of about one quarter of the circle, so that the riveting has to be conducted in two operations. The rivets used for this process are manufactured from specially soft iron, and on the one side take the form of an inverted cone, thus, **V**.

When the riveting machine is screwed firmly into position, and a few blows from a light sledge-hammer have been applied over the blocks to ensure good contact, the piston rivets are inserted into the holes with the prepared end inside, and then hammered by two men armed with riveting hammers. The fine rim of the soft-iron rivet expands on being driven against the cast-iron blocks, and fills the countersunk holes, whilst the spare iron on the outside is simultaneously hammered into a head. Two men may be engaged on opposite sides of the tube at the same time to hasten the work, and when all the rivets are finished, the blocks are slackened out and turned to a new position, and the process repeated. If compressed air is available at the well, pneumatic riveters may be used, and a pneumatic, instantaneous-acting riveting block may take the place of the common screw type. It is usual, when lowering a new column of tubes, to supply them from the works in couples or fours already riveted together, and thus hasten the completion, in which case it is only necessary to replace the suspension rods, and the screwed spindle of the riveting machine by longer ones. Sometimes the riveting of casing is performed with common countersunk-headed rivets, inserted from the inside by means of a suitable lath to which the rivets are attached, the riveting block being subsequently lowered to the collar and the rivets hammered up firmly.

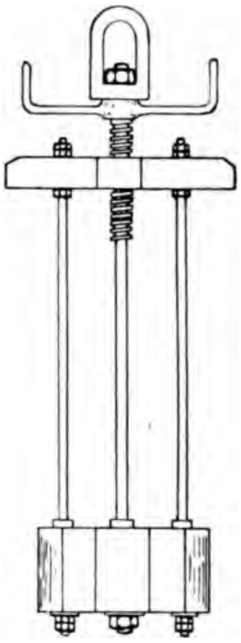

Fig. 43. — Apparatus for Riveting Casing when being lowered in Wells.

Screwed Casing.—Screwed tubes of English, Russian, American, and German manufacture have been to some extent used during the last few years, especially for wells of very small diameter, and no one hesitates to acknowledge the superiority of a seamless tube with its greatly increased resisting power and absence of all inlets for water, provided the screwed joints are reliable. Unfortunately, many of the early attempts with this class of tubing were a complete failure, and earned for it a very disreputable name. Tubes which gave satisfaction and were used without complaint in the American oil fields, were condemned on first trial in the Baku oil territories, and as this is a subject upon which the opinions of experts are divided, it will not be out of place to give a detailed account of the local experience. In Grosny, the geological conditions more nearly approach those of the American fields, and screwed tubes are much more extensively and usefully employed than in the Baku oil regions, where the strata are quite different. In Grosny, a single column of lining tubes may be carried a long distance with little risk of stopping, and even great depths can be bored without lining, thus giving the tubes little work to do. In the Baku district the success of a well largely depends upon the fulfilment of the clause in the agreement or contract guaranteeing that each column shall, on an average, pass at least 30 sagenes (210 feet) below the shoe of the preceding one. The strata in most districts are such that this end can only be secured by keeping the tubes free, often with much trouble, as they not uncommonly stick fast after having passed several sagenes, and can only be freed by alternately driving with a heavy monkey and raising with jacks. The greater part of the screwed casing would not stand this class of work, and although the tubes used were manufactured by the best known firms in England and America, either the threads stripped or the tubes broke off short at the end of the threads. In isolated cases, the workmen were to blame, as the tubes had never been screwed to butt, but in the majority of instances, no qualifying excuse could be found, and the fracture was due to undoubted defects. To prevent the stripping of the threads, the collars were riveted to one end of the casing previously to transporting to the well, and after screwing to butt in the derrick, the other half was drilled and tapped to receive a series of ¾-inch slotted-headed screws which lay flush with the tube inside and outside. This extra labour was successful so far as it prevented the threads from stripping, but the tubes then separated at the end of the threaded portion, and it was seen that, in the majority of cases, they had never been perfectly circular, and that the iron had been cut almost through on two sides in the screwing. As a last resource, a large consignment of expensive screwed casing was in one example transferred to the lathe, the threads cut off entirely, and riveted collars 16 inches wide fixed in their place, after which no more trouble was experienced.

Users of screwed tubes should stipulate, when ordering for Baku wells, the following conditions in the specification, and receive satisfactory guarantees that the details will be minutely carried out:—

1. Extra long sockets equal to the diameter or 1¼ times the diameter of tube.
2. A guarantee to be given that the threads shall be cut evenly and not deeper on one side than another, and that the tubes shall be perfectly circular.
3. The tubes to butt at the moment the taper threads are screwed up quite tightly.
4. Both tubes and sockets to be chamfered at the edges to simplify the starting in screwing up and to prevent burrs.
5. Extra coarse threads, about nine to the inch, to be provided for increased speed in screwing up, and better wearing qualities.
6. Special protective measures to be arranged for assuring the arrival of the tubes at their destination in a good state, by inserting strong rings or plugs into the ends of the sockets and attaching heavy collars to the exposed screwed end.
7. Nowhere must the tubes be less than ¼ inch in thickness.

Many of the protective measures for tubes were quite inadequate, and in numerous cases both the screwed ends and the sockets were badly damaged in transit, on account of the light character of the protective rings. If all the conditions are fulfilled, there is no doubt of the efficacy of screwed casing when once inserted, and its presence in a well gives a very substantial security, and, in case of a fountain, greatly increased confidence. In most wells where screwed casing is sunk, its use is confined to the lower parts of the column, where the greatest danger exists, the remainder being composed of common riveted casing that is attached to the screwed variety by a connecting piece. If a strong fountain is suspected, or if it is the intention of the owner to shut down the fountain by means of some appliance, the screwed tubes should certainly be continued to the surface.

Tube-clamps.—To enable well casing to be manipulated with safety and care, very heavy wrought-iron tube-clamps, made in two halves, are bolted to the tubes, which they must accurately encircle and firmly grasp. Before the clamps are fixed in a new position, the casing should be cleaned and freed from grease and sand, and, as an additional precaution, the clamps should be placed immediately beneath a collar before any weight is permitted to rest upon them. The tube-clamps are shown in use in Fig. 47; but where the column of tubes is a heavy one—for a column of tubes will often weigh 40 tons (2500 poods) —two or three pairs are attached for safety.

Where double tubes are used, no collars exist against which the clamps can find support, and a special class, provided with taper wedge pieces, has been designed to meet the exigency. The clamps for double tubes are either made in halves, and held together by bolts, or are formed from a solid ring in which grooves are planed to receive the taper wedges which grasp the tube. With this class of clamp, the greater the weight of the casing the greater is the pressure thrown on the wedge pieces, and consequently the firmer they grip the sides of the casing. It is scarcely necessary to emphasize the importance of using properly tested pipe-clamps, and discarding any which show signs of the slightest defect, as a most serious accident may accompany the fall of a heavy column of tubes in a well, and months and months of work result from a fractured clamp. Partly with the object of minimizing the effect of such a disaster, and partly to act as a guide, especially if other tubes have been cut out, a wooden plug is always inserted in the shoe of a new column, which serves to steady the motion of the column when passing through the liquid, and considerably checks the velocity of a fall when the liquid is reached if a tube-clamp should break. In one case, a column of 14-inch tubes, weighing 5 tons, fell a distance of several hundred feet to the surface of the liquid, and then passed a further 1000 feet before the bottom was reached, but the wooden plug performed its duty, and although it was driven by the force of the impact completely through more than 200 feet of casing, it steadied the fall to such an extent that the tubes were undamaged. In another case, where there were only a few feet of liquid, the fall of some 10 tons of casing nearly 500 feet led to a complete collapse, and many months were spent freeing the bore-hole.

Raising Lost Tubes.—When a column of tubes is dropped, either through carelessness or some breakage of the machinery, and the fall has been a considerable distance, it is quite certain that, in cases where the quantity of liquid in the well is small, it will have sunk a long distance into the ground, besides becoming considerably damaged. No half-hearted attempts should therefore be commenced, or the break-down will be aggravated by the loss of fishing tools and rods also. The instrument employed for raising tubes is termed a *tube-*

raiser, or *tube-catcher*, and a common Russian form is shown in Fig. 44; it is of massive construction and great strength, capable of resisting an immense tensile strain.

The tool is lowered on 2½-inch or 3-inch fishing rods usually, and the wedge-block is drawn up by rotating the screw by means of the rods until a very firm hold has been secured, after which jacks may be placed beneath massive rod-clamps, and power applied. The operation of tightening up this instrument is most dangerous, for, to ensure a firm hold, considerable power must be applied to levers attached to the rods, and either a pulley-block or a rope wound round the drum of the boring machine is used to obtain the necessary force. The torsion in a length of rods 1000 to 1500 feet long is immense, and the torsional energy, if allowed to suddenly relieve itself through a fracture of the rods or levers, will cause dreadful havoc; indeed, in one instance, where a lever snapped, the whole engine-shed collapsed from the vibration caused by the violently untwisting rods. Men who unfortunately are in the path of the levers when one of the ropes or blocks breaks, are flung in a mangled condition in all directions, like so many pieces of paper, and when doing such dangerous work the employee in charge should insist upon the men keeping at a safe distance. Sometimes the ordinary fishing rods are insufficient to free the lost tubes, in which case the instrument is often lowered on stout, riveted well casing, and after being firmly tightened up, this is jacked. If this fails to move the lost tubes when the maximum tensional strain has been applied, the last resource is to unscrew and raise the instrument, lower a tube-cutter, and cut pieces off, raising each portion separately with the tube-catcher, as detached. If the whole of the lost tubes cannot be removed in this way, the last few pieces must be cut up with boring tools, an operation which may take many months to complete, and cost a lot of money in special tools and repairs to instruments.

Tube-cutters.—In order to make cementing possible, and to economize casing, it is usual to cut out and remove part of the tubes from wells, for which purpose special tube-cutters are constructed which are capable of cutting tubes at considerable depths, by a rotating motion transmitted to them by means of rods from the surface. Formerly all tube-cutters were lowered on 2-inch or 2½-inch rods, which made the process of severing the casing a lengthy one, but very neat tube-cutters are now made which may be lowered on ordinary 1¼-inch boring rods, and which rarely fail in their action. The usual design consists of a cast-iron fitting, provided with three or four arms, in which circular or rectangular fingers, holding circular steel roller cutters on the outer edge, can move. The projections are pressed towards the main body of the instrument by springs, and through the centre of the apparatus moves a long tapered cone spindle, which, when revolved, is drawn downwards by means of a screwed portion at its end, working in a nut which is kept stationary by suitable means. Guides fitted above and below the cutter keep the tool quite central, and the lower guide is provided with the nut in which the spindle works, and is prevented from rotating with the rest of the apparatus by a spring which expands and comes firmly in contact with the side of the tubes. The top end of the cone is just large enough to cause the cutters to pierce completely through the casing, and by continuing to revolve the spindle still further, a diminished portion of the spindle is reached into which the fingers with the cutters are forced by the before-named spring, the cutter thus escaping contact with the casing during ascent. Fig. 45 shows a good type of tube-cutter.

Before cutting is commenced, screw jacks or hydraulic jacks should be placed beneath the tube-clamps, and the casing kept in a state of tension whilst the process is in progress, so that the upper tubes will lift directly they are severed, and not sink and break the roller cutters. In order that it may be known when the cutters have returned to the recess in the spindle, and are free from contact with the casing, the number of revolutions, previously calculated from the screwed shaft, must be counted. Sometimes it is necessary

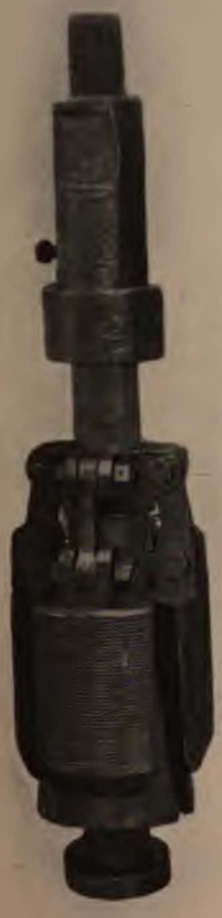

Fig. 44.—Tube-raiser.

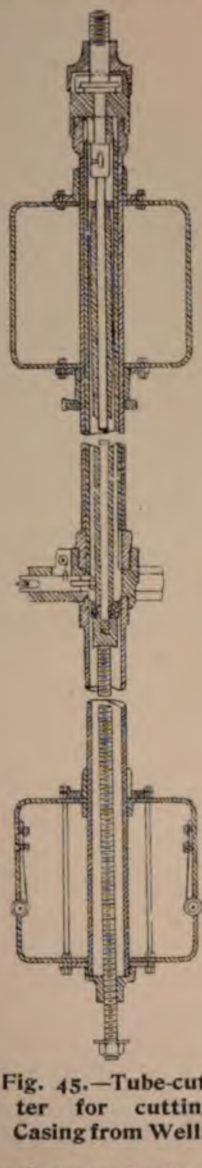

Fig. 45.—Tube-cutter for cutting Casing from Wells.

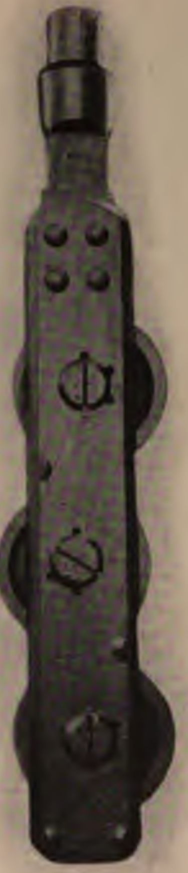

Fig. 46.—Biering's Patent Tube-repairer.

to cut well casing vertically, in which case an instrument is used provided with rollers on one side, and a steel roller cutter placed vertically in a hinged link which can be forced outwards as the cutting proceeds. The feed is applied by rotating the rods on which the tool is lowered, and the cutting is performed by raising and lowering the instrument by means of a rope attached to the rods and worked from the drum of the boring machine. Such cutting is often necessary when sand has accumulated behind the tubes, and prevents them from being lifted after cutting in the ordinary way.

Removing Casing.—When raising a column of well casing after cutting, the tubes are usually uncoupled in pairs or fours, and the rivet heads are sheared off by means of a cold set and sledge-hammer, the body of the rivet being subsequently driven into the well by means of a steel punch. It is better, during this work, to lower into the tubes a light sheet-iron, funnel-shaped vessel, by means of cords, to a point a little below where the rivets are being driven in, as the fallen shanks do not then form an accumulation in the well, but are raised in the funnel after each joint is disconnected.

Repairing Bulged Casing.—Lining tubes are frequently bulged during boring, either from too heavy driving with a "monkey," or from a side-thrust due to a fall of strata. Such an accident is, as a rule, easily repaired by lowering, on heavy fishing rods, conical-shaped tools called "drifts" or "expanders," and causing several, of increasing size, to be forced past the damaged spot. The common form of drift used in the Russian oil fields consists of a heavy, square, wrought-iron rod, fitted with a screwed connection at its upper end to suit the rods, and provided at the lower end with a nut working on a screwed portion. The intermediate part of the rod is fitted with a series of interchangeable, circular discs, which diminish in diameter from the centre—where the largest-sized disc chosen is placed—towards the ends; thus producing the equivalent to a solid double-tapered drift. By adding or abstracting discs, the size of the drift may be varied, and as each size is made to pass freely through the bulged casing, the tool is raised, larger discs attached, and the process repeated until the original size of the tubes is reached.

Mr. Biering has recently patented an improved form of drift, which should attract a deal of attention, as it removes one of the chief objections to the common form of drift, namely, friction. Fig. 46 shows Biering's patent drift, which, it will be observed, is provided with rollers, the spindles upon which they revolve being arranged in such a way, by means of an eccentric device, that they can be extended outwards or drawn inwards at will, and so made to form an expander of variable size.

The extent of the bulge is first ascertained by lowering seals or other instruments, after which the expander, regulated to proper proportions, is lowered and caused to pass the place several times slowly, the weight of the rods assuring the downward passage, and the lifting being conducted from the boring machine. After the tool passes freely it is raised, additional larger blocks added or the rollers adjusted, and the operation repeated until the full size is reached.

Advantages of Different Classes of Tubes.—The views held concerning the relative values of different types of casing are varied, and whilst some experts stoutly proclaim the special advantages secured by screwed and double casing, others as stoutly maintain that the disadvantages more than counterbalance improvements. It is obvious that double casing, or $\frac{5}{16}$-inch casing, is stronger than single $\frac{3}{16}$-inch or $\frac{1}{4}$-inch, and will resist a much greater external collapsing pressure, but in practice it is found that tubes rarely break from evenly distributed forces, but almost invariably from lateral thrusts caused by slips and motions of strata. Under such circumstances, it is fairly certain that in the greatest proportion of fractures the well would not be saved by a slight increase in the thickness of iron, and it is even doubtful whether a rod of iron equal in diameter to the size of the tube would resist the movement of hundreds of tons of sand without deflection. Where the string of casing is deeply embedded in a soft, highly productive oil sand, it practically amounts to suspension in a fluid mass, and the immersed portion of the column is affected by any movements of the sand. Neither double tubes, thick iron casing, nor screwed tubes will resist this action, but the drawbacks to their use are discovered when repairs are required, or deepening is needed, the amount of iron in the thicker varieties enormously complicating the nature of the work and prolonging the time. In Grosny these difficulties are not met with, and consequently the above arguments do not equally apply to that field; in fact, the better the quality of the casing, the longer will be its life in the well. As in other things, discretion must be used in deciding the best quality of tubes for a particular district, for it is a well-known fact that, whilst in many regions tubes almost invariably run out of vertical and ultimately fracture, in other parts of the field the same phenomenon is rare, and strong tubes may be used with advantage. As the oil sands become more exhausted by active exploitation, the density of the strata is diminished, and naturally the sand gravitates towards the point from which the oil and sand are being extracted in greatest quantities. Landslips on some congested districts have reached a serious stage, and where a number of wells are drawing oil from the same source, the life of the casing in a new well does not exceed a few months.

Protective or Preservative Columns.—Opinion is divided on the practical utility of sinking protective columns, and the arguments raised against the use of double tubes apply almost equally to the employment of a protective column. Under certain circumstances their value cannot be denied, and their presence is a substantial support to a well otherwise decidedly weak. If the column of tubes which penetrates the oil formation has passed more than 100 feet to 150 feet below the previous column, in ground of a loose nature, a protective column should not, as a rule, be omitted, and in all cases where a fountain is expected, such a column should be lowered to protect the preceding string from the destructive abrasion caused by the sand. Screwed casing is too expensive for use in wells of large diameter, but for bore-holes 12 inches or less in diameter, it should without exception be employed where spouters are expected.

The table below shows—

(1) The capacities of tubes in cubic feet per foot of depth.
(2) The pounds of water per foot (62·425 lbs. per cubic foot).
(3) The poods of oil per foot (54 lbs. per cubic foot).

column may be converted into imperial gallons by moving nt one place to the left.

TABLE XVIII.

Tubes per Foot of Length, from 8 Inches to 30 inches Diameter.

	feet t and area.	Pounds of water per foot.	Poods of oil per foot.	Diameter.	Cubic feet per foot and area.	Pounds of water per foot.	Poods of oil per foot.
				Inches.			
	0·3491	21·79	0·524	20	2·182	136·19	3·273
10	0·5454	34·05	0·818	22	2·640	164·79	3·960
	0·7854	49·03	[illegible]		3·142	196·11	4·713
	1·069	66·73	1·603	..	3·687	230·16	5·530
	1·396	87·16	2·094		4·276	266·93	6 414
	1·767	110·31	2·650		4·909	306·43	7·363

CHAPTER VII.

PROCESSES OF EXCLUDING WATER FROM OIL WELLS.

Remarks on the Exclusion of Water from Oil Wells.—Serious and far-reaching results of neglect to note occurrence of water in boring—Illustrative examples—Adequate attention to exclusion of water only very recent—Fears as to fountain-hunting and consequent reckless boring permanently injuring new properties.

Methods of excluding Water.—Many schemes proposed and used—Primitive plan of utilizing expansive effect of water on vegetable material—Failure in use of asphalt—Advantages and disadvantages of and occasions for use of sand—Clay, necessary treatment, scarcity of suitable clay in Baku district.

Cementing Wells.—Cement almost exclusively used—Care necessary in its use—Details of cementing: preliminary plugging, preparation and introduction of cement, class of water for mixing with cement, brands of cement—Importance of sparing no pains to make cementing successful—Second cementation where necessary—Methods—Advantages and drawbacks of cementing as boring proceeds—Success of cementing dependent on character of strata—Remarks on character of Portland cement—Objections to cementing—Cement, composition and hardening—A quick-setting variety—Under-reaming in boring unavoidable at Baku—Importance of judgment as to point at which cementing should be done.

Other Methods of excluding Water from Bore-holes.—Insertion of lead and composition rings at points where lining tubes are cut out—"Packers" in little favour in Russia—Details of one tested at Baku—Conditions of ground for a packer to be successful—Suggested freezing of ground round bore-hole—Objections to this method—Advantages of screwed casing in connection with exclusion of water.

Tracing of Subterranean Movements of Water.—Use of fluoresceïn—Results doubtful, but such as to warrant fuller investigation.

CHAPTER VII.

PROCESSES OF EXCLUDING WATER FROM OIL WELLS.

Remarks on the Exclusion of Water from Oil Wells.—In the early life of the Baku oil fields scarcely a well could be bored in the rich district then exploited without reaching oil, at a moderate depth, in large quantities, and generally a fountain. Wells were bored as rapidly as the primitive boring appliances at the disposal of the local proprietors permitted, and no attempts were made to exclude the surface and other water with which some of the intermediate strata were impregnated. The strong gas pressure met with at this time in even shallow borings was sufficient, in most cases, to prevent the inlet of water into the oil sources, and when the gas was exhausted to such an extent that spouting ceased, and water was admitted, the wells were deepened to a more prolific source. The irrecoverable injury so done to large areas has now been realized, and not only do up-to-date oil proprietors take special measures to exclude water, but most observers perceive that it is a necessary procedure if the oil fields are to be preserved from complete ruin.

Engineers now make strenuous efforts for permanently and securely shutting off water, and although no legislation has been enforced dealing with the question, as in some other countries, it is the only way of preventing properties from falling under the category of water producers only.

In a carelessly bored well, carried down either by an unconscientious contractor, or a reckless boring master, careful observations are not made, nor important details noted or communicated to the engineer, the object of the men being confined to boring as many feet as possible within the 24 hours. Water sources are struck and passed unheeded without a notice, with the result that the overhead water follows down behind the casing unknown until an oil stratum is reached. Unless the gas pressure is sufficient to overcome the water-head, the oil sand, which under normal conditions is at once recognizable by its discolouration and odour, is so washed by the flow of water that it is perfectly white and inodorous, and is generally recorded in the boring journals as water sand. Many a rich oil stratum has been passed in this manner, and many records exist of thousands of pounds wasted through such culpable oversight. The loss of a well at a shallow depth is but the beginning of a long series of disasters which usually follow, for the water flows behind the casing into the oil sand, which it impregnates and dilutes to a large extent; and although the amount may be insignificant and scarcely worthy of notice at first, its continual motion rapidly enlarges a pathway, until the water finds a ready inlet into the porous sand. Temporary resistances, such as falls of impervious ground against the sides of the casing, are washed away, and unless circumstances are unusually favourable, failure, almost certainly, is the outcome.

In many cases, and formerly in most instances, the gas pressure, indicated by the level of oil in the well, exceeds that of the water-head, and so for a time prevents the inrush of water into the productive strata, and so long as such is the case no damage occurs through failure to shut off the water, but as soon as the gas pressure decreases and the level of oil falls, the water rushes into the well and displaces the oil. When once the water has got the upper hand, the quantity of oil diminishes, whilst there is a correspondingly increased amount of water, and although the gas may continue to be liberated for a long time after the disappearance of the oil, the fate of the well is sealed, and the end approaches with astonishing rapidity. As a matter of fact, the best, longest, and least troublesome life of the well has never been reached in many cases, as it is only after the gas has diminished and the yield of sand decreased that a well's normal and regular output is obtained, which may continue for many years.

The effect of such careless operations is not confined to the one faulty well. Its action is far-reaching, and besides seriously injuring, or ruining adjacent wells on the same plot, its influence extends to those on neighbouring properties. The course of the water admitted into the oil stratum is decided by local circumstances, but its tendency is to flow towards the points of least resistance, which, in the neighbourhood of other bailing wells, is in their direction. When water has reached a second or several other wells, the oil they contain is gradually displaced, and a direct unrestricted communication, is soon established—for water possesses greater fluidity than oil—between the faulty bore-hole and other wells within its sphere of influence. It is for this reason that it is sometimes advisable to bail water-yielding wells at a loss, in order to prevent water from diverting its course into a near well which is highly productive. During the recent commercial crisis (1902), many firms shut down wells which gave a small unremunerative output of oil and yielded a large proportion of water, but the scheme was fatal to the remainder of the property, for immediately the former good producers fell off and gave mostly water. The stoppage of bailing in a well giving chiefly water is very commonly followed by the flooding of a neighbouring well on an adjacent property, the current of water being deflected towards a new point of abstraction when the former inducement ceased.

Mention could be made of whole properties being shut down through flooding by water, upon which it would be wasted expenditure to locate new wells, but which, had ordinary precautions been taken, might be producing oil to-day. In one case, illustrative of the subject, a good periodical spouter was struck on a property not largely exploited, and it led to the boring of a number of wells in the immediate vicinity. There was only one aim of all, namely, to reach the new proven source, and in their anxiety to be first down, scarcely any one attempted to shut off surface water; the end of this mad rush being that an area of 5 acres was flooded, and no less than twelve wells were eventually abandoned, as only water was obtained from them.

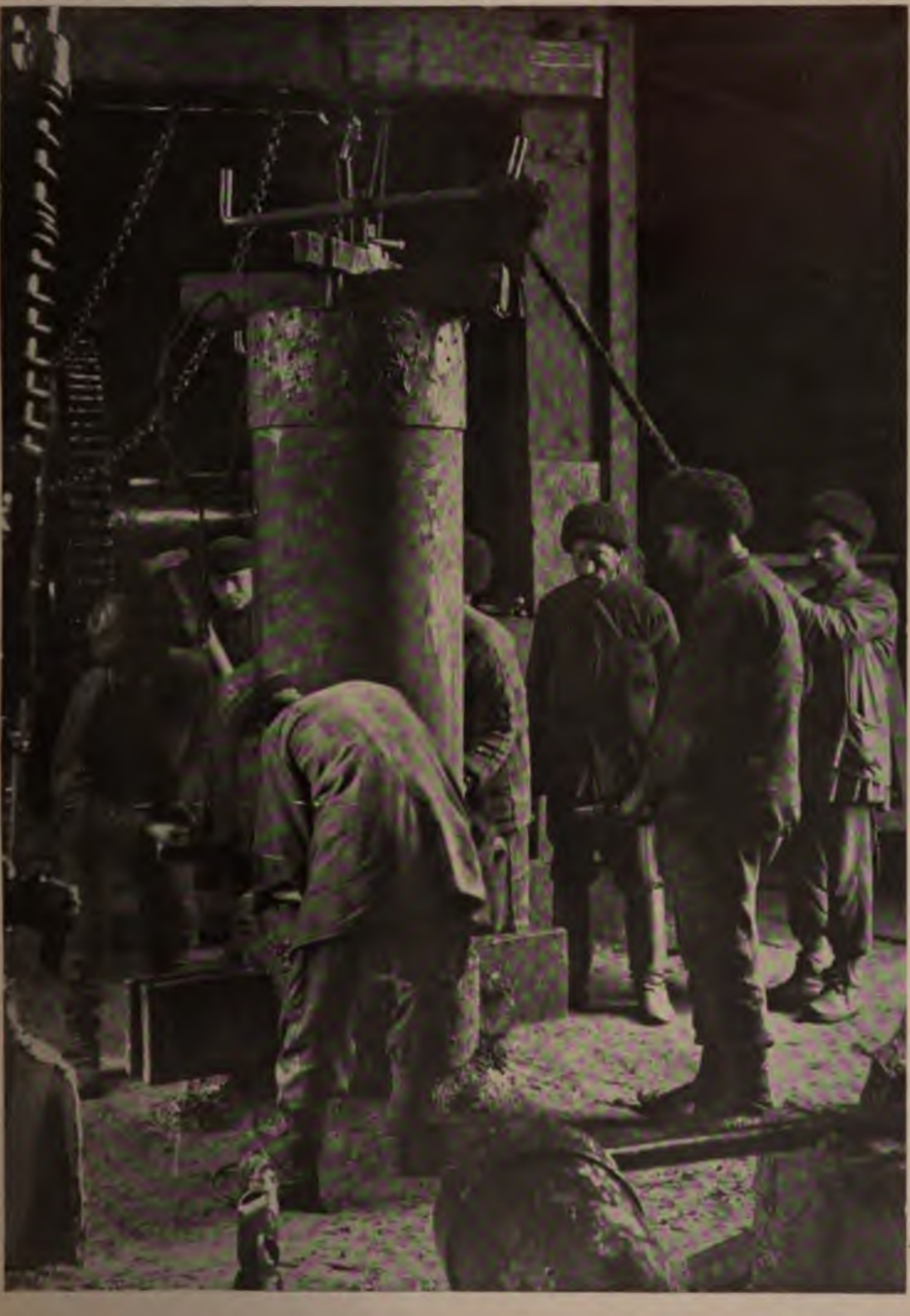

Fig. 47.—Persian Workmen Riveting Casing in a Baku Oil Well.

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Few companies, until a year or two ago, paid sufficient attention to this important and, at present, vital branch of the Baku oil industry, although its value was generally acknowledged; but more consideration is daily given to the subject. The usual practice was, as already explained, to go on blindly boring until an oil source was reached powerful enough to overcome the water, and to yield for a time a big output—a system recklessly employed by some of the pioneer explorers of new lands. The results have been disastrous in numerous cases, for the owners have bored on and on, in the hope of striking a big producer at any moment which would repay all the expenditure; but unfortunately, many of the new lands have not turned out so prolific as the old Saboontchy field, and the negligent explorers have been forced to abandon their search at great depths, and have had the chagrin of seeing more cautious proprietors, close by, obtain big producers at shallow depths by observing proper precautions.

It is to be feared that the excitement following the leasing of plots in the Bibi-Eibat oil field will lead to a lot of reckless boring caused by fountain-hunting, which will permanently injure the properties. In the Romany-Zabrat region most experts prophesied that oil would never be reached at less than 1400 feet, and really no heed was paid until this depth was approached; but, in reality, excellent bailing wells have been completed (1902) at 800 to 1200 feet, some of which have turned out periodical fountains (plots 20, 33, 36, 70, 71, 72). In the Zabrat district there are numbers of unproductive test wells at 1600 to 2000 feet deep, which are quite barren, but as the water-level lies within a few feet of the surface, no one can call the results conclusive, and there is little doubt, in the author's mind, that these plots will eventually be found productive.

Methods of excluding Water.—Since every one now recognizes the importance, and in many cases the absolute necessity, of effectually excluding water from oil wells, it is not surprising that a number of schemes and contrivances should be forthcoming for dealing with the problem. A brief description will be given of the various methods and devices tried, with an outline of the most obvious objectionable features; and only minute details will be given of the more general and successful systems in use. In order to simplify the process of closing the water, as well as to economize casing, it is the usual practice to cut out a number of the tubes, as shown in the adjoined section, each column being severed a little above the shoe of the preceding string; thus leaving a space which allows the insertion of some impermeable substance which effectually excludes water (see Fig. 48).

Amongst the earliest suggestions was the idea of depositing between the cut casing bags of beans, bran, and such-like materials which, after prolonged contact with water, swelled enormously through absorption, and exerted great expansive force. The powerful pressure so obtained was utilized to form a water-proof collar which prevented the flow of water into the well, but sand or clay was also run into the space above the collar to act as an additional support. The objections to this primitive process were the uncertainty of its action, the difficulty of ensuring the materials reaching their proper destination, and its non-permanent character.

Another early system was the utilization of asphalt, which was poured in a liquid form between the casings, with the object of forming, when cool, a solid composition, through which water could not permeate; but no success was attained which warranted frequent repetition. To enable the composition to reach its destination without solidification, the asphalt was kept liquid during its descent by heating up the water with steam, otherwise the meeting of the two liquids would have produced early congelation; but notwithstanding repeated attempts it could never be made to set reliably, and was generally bailed out with the oil after a short time. Asphalt deposited in the wells in this manner never solidified entirely, even after long standing, probably due to the presence of oil and the absence of atmospheric drying agencies, and it was consequently a source of danger to the well, as the heavy viscous mixture exerted an enormous external pressure on the casing, threatening a collapse whenever the level of liquid in the well fell.

Other methods commonly practised are conducted with the aid of sand, clay, cement, and mixtures of sand and cement, inserted in the space intervening between the casings. An attempt will be made to explain the respective value of each material; it must, however, be noted that no definite advice can be offered at random for any particular well, as different conditions render an alteration in the operations desirable.

Sand possesses the advantages that it is cheap and plentiful, sinks freely in water, is unaffected by oil, and forms a solid compact bed when precipitated from water; but, unfortunately, it possesses the property of porosity. The filling is performed by pouring a well-agitated mixture of sand and water through a funnel and pipe into the space where the casings are removed, where it gradually settles and primarily forms a water-tight sediment. When bailing is resumed there is a tendency for the sand at the bottom to sink and follow the direction of the stream of oil, and after motion has once been imparted to the particles, the remainder in a very short time follows, and water breaks in. The use of sand is confined to wells where the condition of the casing is good; for if the tubes are badly eroded, or the rivets loose, the whole of the sand will in a very short time find its way into the well and be bailed out. In some cases a perfect shut-off has been established for weeks and months by this means, and an excellent production of oil has temporarily been obtained; but in nearly all examples the wells have been finally flooded. The sand process has one distinct advantage which cannot be claimed for other systems, namely, that the sand generally runs entirely away, and can easily, cheaply, and quickly be replaced, after which good results may often be attained. Sand cannot be recommended for most cases, but in special circumstances excellent results may and have been secured by its use, as the following details of an example in the Bibi-Eibat field will testify. A well was an intermittent spouter, yielding on an average nearly 20,000 poods a day, but, unfortunately, the water had never been properly excluded, and it periodically broke in and caused the flowing of oil to cease. On each occasion a short stoppage was made, and fine sand inserted between the casings, with the result that when bailing was resumed the well recovered its old state and yielded its usual production. If the tubes are known to be the least faulty, the addition of a small quantity of coarser grained sand may be found beneficial, as the larger particles will drift towards, and assist to arrest the passage of water through any leaky rivet-holes or imperfectly caulked joints, through which fine sand would escape. The best results obtained with sand have followed the use of a very fine sharp-grained variety taken from water wells in the Zabrat region and elsewhere, which settles very compactly after filtration through water.

Clay is a deposit which owes its highly impervious qualities to its minute fineness of grain, a property which, at first sight, renders it invaluable for water-closing purposes; but in order to convert it into a condition suitable for running into the space between the tubes it must undergo treatment. The clay requires drying and grinding, to crush all solid particles, and to convert it into a fine powder before mixing with water and running into the well, none of which processes has been properly carried out, so far as can be learned by the author. Good clean clay is not readily obtainable in the Baku districts, and although it has been tried to some extent, it has not been largely brought into use.

Cementing Wells.—Cement has been the most popular substance in use for several years for shutting off water; indeed, is now almost exclusively employed for this purpose, and the term "cementing" has acquired a local meaning of excluding water. Although cement has been proved to be a most reliable material in the hands of skilful persons, it is almost worthless unless great care is exercised in its manipulation; for cement, of all the substances mentioned, is least adapted, theoretically, for local requirements, and its application can only be made successful when certain conditions have been complied with. Cement is spoiled by contact with oil, and its setting qualities are destroyed or seriously injured by the presence of enormous quantities of salt and other chemical compounds in the water; it is expensive to purchase, and it is difficult to store and preserve from deterioration; yet cement is the one substance by which alone permanent results can be attained. Cement cannot be indiscriminately employed, and the correct moment for conducting the cementation must be discreetly decided by the engineer, for if the process is postponed too long, strong gas or a high level of oil may introduce difficulties which considerably complicate matters. An instance where cement would have been quite useless is the Bibi-Eibat example already quoted, where sand was so successfully utilized, but where no hope could be entertained of cement setting in the presence of such gas and oil.

As the cementing process is one of the most important branches of the oil business, a full description will be given of the arrangements adopted by the principal companies in the Baku territories.

On referring to the section of a well prepared for cementing (Fig. 48), it will be observed that the 14-inch, 18-inch, and 20-inch casings have been cut out and removed, leaving clear spaces between the 12-inch and 16-inch, and the 16-inch and 22-inch casings, wherein the cement may be deposited. Suppose the level of water in the well to be 30 sagenes (210 feet) from the surface, the 14-inch tubes to be cut out at 160 sagenes (1120 feet), and the 18-inch and 20-inch to be cut out at 700 feet and 490 feet respectively; and water-bearing beds to exist at A, B, and C. The combined water from the three sources will find its level in the space between the tubes and in the well, *viâ* the shoe of the 12-inch tubes, or through faulty seams or rivet-holes which invariably exist in the riveted type of casing. For an absolutely perfect shut-off to be secured, all the channels by which water can by any possible means find admission to the well must be closed; but it is at once apparent that the lower portion constitutes both the most important section and the most difficult in which to perform this operation.

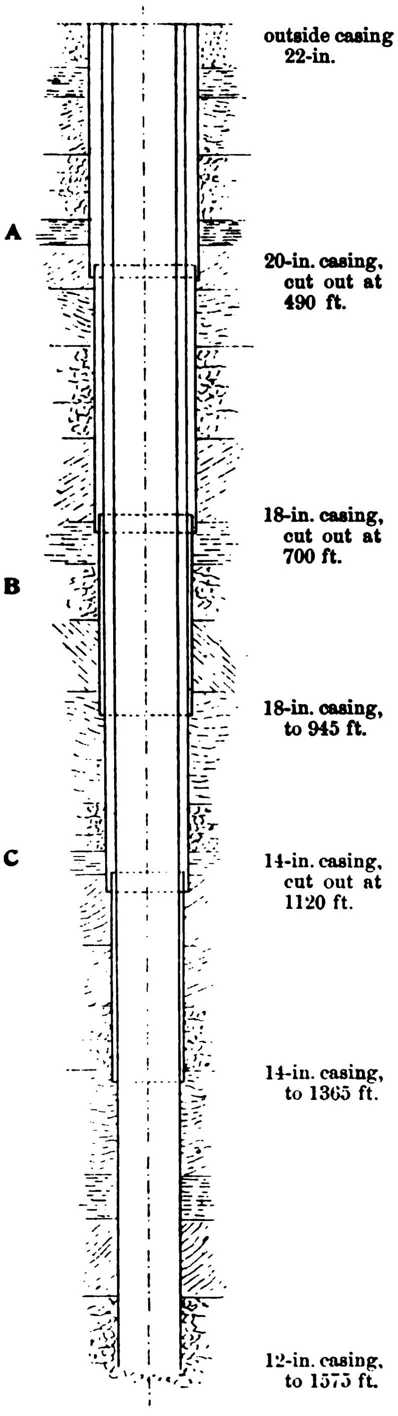
outside casing 22-in.
A
20-in. casing, cut out at 490 ft.
18-in. casing, cut out at 700 ft.
B
18-in. casing, to 945 ft.
C
14-in. casing, cut out at 1120 ft.
14-in. casing, to 1365 ft.
12-in. casing, to 1575 ft.

Fig. 48—Showing Section of Well prepared for Cementing.

Water is nearly always present in oil wells previously to the adoption of measures for its exclusion, and this makes it necessary that the cement should be conveyed to its ultimate destination in tubes, and not allowed to infiltrate through a long column of water before final settlement. Where only a single column of casing is removed, the largest size of tube which will pass with freedom is ¾-inch, but where two (as in Fig. 48) or more strings of casing are cut out, larger sized tubes may be inserted, and where several columns are cut at different depths, the size of tube may be correspondingly increased towards the top.

The tubes employed for cementing purposes are generally common gas pipes, but these are most unsuitable for the work, as the threads are short, and if the sockets catch beneath a collar of the casing during their withdrawal, the tubes break and many are irrecoverable. Flush-jointed, high-pressure tubes with extra long screwed sockets should be specially ordered for this class of work, and it will be found that the initial extra expense will be quickly repaid.

As a preliminary to cementing, the well must be filled up with sand, clay, or a mixture of the two, to prevent the escape of any cement into the interior of the well, which might percolate through leaky joints or rivet-holes in the casing, and to counterbalance the weight of the cement behind the casing until it has had sufficient time to set hard. Different authorities recommend different kinds of plugging, but it is really immaterial what is used for the purpose so far as attaining its object is concerned, but the choice of material should be decided by the ease with which it may be removed after the completion of the process. It is natural that the substance nearest at hand should be chosen for depositing in the well, but it should not be indiscriminately used, as some qualities of sand settle so compactly under water as to require boring through. Clay, or a mixture of clay and sand, forms a very useful plugging for wells, as it can be very rapidly cleaned out; indeed, 40 to 50 sagenes may often be bailed out or bored through in 24 hours, but it must always be rammed to ensure a compact, homogeneous plug. The local yellow sands and fine white sands should always be avoided, as they form a very hard plug which often takes weeks to clean; but oil sand, in the absence of clay, may be used with success, and it is generally not very troublesome to clean out.

The plugging material must be deposited with care, a sufficient interval being allowed to elapse between each successive charge for it to settle in the liquid, otherwise the air, assimilated in the body of the mass, does not disengage itself, and an air-piston is formed that prevents settlement, and causes an unfilled space to be left in the liquid. This is a very common occurrence even when moderate care is taken to avoid its formation, and for this reason a rammer should be lowered, from time to time, to ascertain the extent of the progress. When such an air-piston is suspected or discovered, the deposited material must be cleaned out as far as the faulty or doubtful position, and the work of filling repeated.

Water must be pumped into the well to facilitate the removal of the plug, but when the end is approaching oil should be used instead of water if the plug is very hard, and the liquid should be frequently supplemented to keep the level near to the position the subsequent oil level is expected to attain. The last 20 to 50 sagenes of plug are often removed very rapidly through the oozing of the oil or gas through its mass from beneath.

Before cementing is commenced, but after the completion of the filling operation, clean sea water is usually pumped through the cementing tubes at a high pressure, to thoroughly wash out the space between the casings, remove any accumulation of oil, and displace the well water which is usually contaminated with injurious chemical compounds.

Formerly a mixture of cement and sand was well agitated in a wooden tub, situated at the surface of the well, with sufficient water to form a fluid of a consistency which would enable it to flow with ease through the tubes. From ten to twenty barrels of cement were mixed with a corresponding number of barrels of clean sand, and the whole, after admixture with water, was poured into a funnel provided with a gauze sieve, which led to the cement tubes. The operation was generally repeated every second day, the intermediate days being allowed for the cement to set, until towards the end of the process a larger proportion of sand was added, and the procedure was performed every day. The advocates of the above "diluted and slow setting" practice were often disappointed at the results of their lengthy and expensive work, upon which so much care had been expended, but one fact had been overlooked which was, perhaps, responsible for more failures than any other feature.

As already stated, it is the bottom 20 to 30 sagenes upon which rests the bulk of the work in most cases, and upon the success of this section depends often the value of the whole undertaking. If a mixture of sand and cement is allowed to sink in a long column of liquid, it will be observed that the heavier particles of sand immediately separate and rapidly settle, whilst the lighter particles of cement are precipitated very slowly, and ultimately form a distinct layer upon the surface of the deposited sand. The conditions usually found in nature are similar to this, and on reference to the section it will be seen that the cementing mixture has to infiltrate through from 210 to 280 feet of water before reaching its destination, during which interval the sand and cement will part company, and be precipitated in separate laminæ. The effect is even exaggerated where small quantities are used at a single operation, as the formation of still more distinct layers is encouraged. When the cementing fluid has reached the point where the 14-inch tubes are cut out, there are no more difficulties, as the cementing tubes may be kept immediately above or just immersed in the mixture, and raised from time to time as the filling progresses.

In order to obviate the chances of failure from the above-mentioned cause, many firms now use pure cement exclusively for the first two or three operations, afterwards filling up in the ordinary manner with a mixture of sand and cement, but always keeping the pipes in or near to the level of the cementing fluid in the well. In practice it has been found advantageous to run in a big charge of cement at the first operation—not insert it in driblets, as is frequently done—and it is not an uncommon plan to use fifty, seventy, and even a hundred barrels of cement at one time, the whole being mixed and poured in without any interval by relays of workmen. The greater effectuality may probably be explained by the fact that any flow of water which may be moving towards the well or to a porous stratum might carry small quantities of cement with it, and so keep open channels in the cement, whilst a large volume, deposited without cessation, might exert sufficient pressure to arrest the flow entirely.

To facilitate the work of mixing the cement and running it into position, various arrangements are used, but the principle is the same in all cases. A constant and reliable supply of water must be obtainable, and should be conveyed to the well by tubing fitted with suitable valves and pipe connections. A small hand force-pump should be inserted in the system of tubes so that pressure may be applied and water pumped down if the tubes get choked, or the free flow of the cement is impeded during the process. A wide-mouthed funnel is attached to the upper end of the cementing tubes, provided with a fine brass gauze sieve to arrest the passage of any large particles which might otherwise accidentally enter and clog the tubes.

The mixing of the cement, which has previously been passed in a dry state through a sieve, and freed from foreign substances, is executed simultaneously in two wooden tubs or iron cisterns, conveniently placed near the surface of the well, to which water is conducted by tubes with a cock at each tub. The workmen, armed with shovels, stir up the mixture, adding more cement from time to time, and regulating the water supply by the cocks to maintain an even consistency and homogeneous fluid. After thorough agitation, and whilst the men are still engaged stirring, the solution is poured into the funnel with buckets, another party of men being in the meantime employed mixing the second tub. By properly distributing the labourers, a constant flow of thoroughly mixed cement can be run into the cement pipes.

An improved method * of cementing adopted by some companies is performed by arranging on a platform two mixing boxes or tubs in such a position that the bottom of one is just above and slightly extending over the top of the other. In the base of the upper tub is fitted a plug which, when withdrawn, allows the well-stirred cement to run into the lower box, where, after undergoing a second lively agitation, a cock is opened leading direct into the mouth of the funnel.

The next important consideration has reference to the class of water which it is advisable to use with the cement. Nearly all the Baku waters met with in the wells, except the shallow collections in the outlying areas not already contaminated with well water, show, with a salinometer, from 4 per cent. to 14 per cent. of salts, and amongst others they contain in solution salts of calcium and magnesium and sulphur compounds, but they usually exhibit neutrality to litmus. Free carbon dioxide and sulphuretted hydrogen, besides petroleum gases, are also often evolved in great quantities from the wells, and, unless checked, prevent the proper hardening of the cement; indeed, a very little gas is found to have a most deleterious effect upon the hardening qualities of cement. Some oil-well waters do not greatly influence the hardening of cement, but others produce a decidedly adverse effect, and lengthen the period of setting to such an extent that cement would assuredly fail in its object where such a kind was present. Suggestions have been made to deposit chemicals in combination with the cement that will cause the precipitation, in a harmless form, of the injurious compounds held in solution; the liberated acid resulting from the reaction, which might cause rapid oxidization of the casing, being rendered neutral by the addition of a weak alkaline reagent. As the character of the water varies so much in different wells, it is difficult to say precisely what the objectionable compounds in solution are, and the results of a series of investigations, undertaken by the Baku section of the Imperial Russian Technical Society, appear to demonstrate that the difficulties of bad water may be overcome by mechanical means if the process is properly conducted. The committee appointed by the above society reported that the thicker the cementing fluid, the quicker it hardens; that sea water is preferable to distilled water for mixing with cement; that the temperature of the water used for cementing in no way influences the hardening of the cement; that Caspian Sea water is much better for mixing with cement than well water, and that the hardening proceeds more quickly under pressure; that the cement should be conveyed as near as possible to its destination, and not allowed to percolate through a column of water before settlement; that pure cement hardens much better than if adulterated with sand; that the time occupied in mixing the cement has no effect upon its rate of setting; and the committee recommended that Caspian water should be mixed with cement in the proportion of 122 parts by volume of the former to 100 of the latter. The investigations served to emphasize the importance of ensuring

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* First suggested by Mr. Bepple, of Baku.

that only water of suitable quality should come into contact with the cement until the mixture has had time to harden—a condition that it is generally sought to attain by thoroughly washing out the space where the cement is to be deposited with a powerful flush of sea water previous to the operation of cementing. Condensed water, and fresh water taken from wells in the outlying districts, are sometimes used for mixing with the cement, but it is doubtful whether the results are any more successful than where the more popular and convenient Caspian water is employed.

A large variety of Russian cements may be purchased on the oil fields, but they are chiefly "Novorossisk," "Rostoff," and "St. Petersburg," all of which are represented by several manufactures of varying quality; some of the cements are largely adulterated with sand, and these, it is scarcely necessary to add, should be avoided, as such dilution can be locally performed when needed. There is little to choose between reliable makes of any of the Russian cements, which set under water in from one to three days, and become quite hard in a week, and although some imported English cement gave excellent results in several wells where it was employed, a series of experiments demonstrated that it was little better than Russian, and was scarcely worth the extra expense.

When several lengths of casing have been removed, it is desirable to continue the cementing process completely to the surface—the cement in the upper sections being diluted in the proportion of 2 or 3 of sand to 1 of cement—for in addition to the increased safeguard against surface water oozing through faulty tubes at a high level, the well is considerably strengthened, and the life of the casing prolonged by protection from oxidization and sand-blast action.

No precaution should be omitted, when a cementation is undertaken, which will assist in assuring a successful issue; for should the cement in the lower portion of the well not set firmly, or be washed away by a current of water, the upper section, however well executed, will be of little avail, and there is rarely an opportunity for making a simple repetition of the process. A second cementation could only be conducted in exceptional circumstances by the sacrifice of two columns of casing, and unless the conditions permitted one of the supplementary schemes mentioned below, oil at a specified depth would be lost. Casing is sometimes saved by lowering to a point, decided upon by circumstances, an apparatus that pierces an orifice in the tubes, through which cement may be forced from the surface when a suitable appliance for the work has been inserted. Numerous devices could be designed to carry out this work by employing a packer in combination with two columns of pipes, but generally the condition of well casing does not allow the use of such an apparatus, and the work is conducted without any special appliance, as follows: After the holes have been punched or drilled in the lower part of the casing, 2-inch or 3-inch tubes are lowered to a point a little above the perforations in the well, and a thick solution of cement and water is poured down until the level of the mixture reaches well above the pierced section. The cement runs into the perforations, as well as through imperfections in the casing, and fills what space exists behind the tubes, and only when the cement has had sufficient time to set hard is the cement-rock inside the casing drilled out with boring tools. Before commencing such work as the above, the lower part of the well should be well rammed with stiff clay, to prevent too much cement escaping into the lowest stratum. Endless arrangements for cementing could be enumerated, which have been designed for special cases, but an engineer would find little difficulty in devising some appliance to suit a special case if occasion arose.

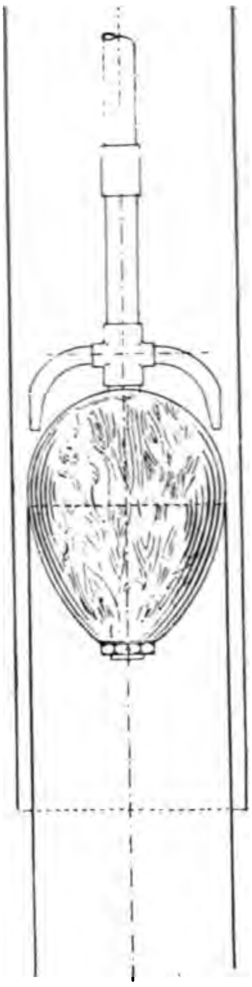

Fig. 49.—Showing Device for Cementing each Column of Tubes as the Boring proceeds.

A system strongly advocated by some engineers is to cement each shoe as the boring work proceeds, by means of an arrangement shown in Fig. 49, composed of a turned, conical wooden plug, above which outlets exist for the passage of cement deposited in 2-inch tubes, on which the block is lowered. The tapered wooden plug, impelled by the weight of the column of 2-inch pipes, forms a perfectly tight joint against the sharp-cut edge of the column of casing, and the cementing fluid flowing behind the casing, reaches to, and probably below the preceding shoe, around which it forms a waterproof block. Some firms even under-ream to a much larger extent than usual beneath each shoe, to a depth of from 6 to 16 feet, when a column of tubes has stopped, thus leaving a larger space wherein the cement may subsequently accumulate and form a large impervious mass. Some authorities assert that this scheme of cementing in stages is not to be recommended, as such small quantities of cement could not in themselves exclude water under a high pressure, and the presence of these blocks of cement only renders more difficult the final operation of filling up the space between two columns separated by the space formerly occupied by one or two strings, postponed to a later period.

Upon the character of the strata in which the cementing is conducted often depends the success of the operation, for whilst clay is naturally the most impervious material, and at first sight the most convenient substance likely to be encountered, it will not unite with cement and form a secure binding, and it is often found in practice that water will carve out a passage between a clay lining of a well and the solid block of cement, thus rendering the process useless. Sands, being more or less porous in nature, will often absorb considerable quantities of cement, and produce a compact, irregular wall, extending some distance from the sides of the casing, that will much more effectually arrest any flow of water than a junction of clay and cement. Sand beds are often avoided for the purposes of cementing solely on account of the large volume of cement that they are capable of absorbing, and the author has personally known cases where 200, 400, and even 1000 barrels of cement, or a mixture of cement and sand, have been deposited in a well before filling commenced, but the results were always successful, and repaid the perseverance expended on them. In known bad water districts it is, therefore, advisable to stop the tubes in a sandy formation as soon as all the water-bearing strata have been passed, and conduct the cementation, and if a large quantity of cement disappears into the ground, so much more reliable will the final results generally be.

It cannot be denied that there are objections to cementing wells, and some Baku mining engineers of distinction have firmly stood their ground in the face of fierce opposition, and insisted that in some districts more loss is sustained by the operation than advantage gained. A thorough cementing excludes all liquid from the bore-hole, whether it be water or oil, to the depth to which the cement reaches, thus precluding all possibility of the well's yield being augmented by oil from other than the lowest source, whereas in uncemented wells the product is, in some cases, to a no small extent increased by infiltrations of petroleum through imperfections in the casing, and the passage of small streams of oil behind the casing, from higher strata. In some old worked districts, where the water is not very troublesome, the riveted type of casing actually forms a type of strainer, through which the oil from one or several sources continually exudes and accumulates in the well, the collective quantity making the well a moderate producer, where each bed separately does not reach the minimum limit for profit. Few firms who hold lands in the Balakhany oil field can have failed to observe numerous wells of this type, and were water-tight, screwed tubes employed, or cementing systematically conducted, the yield of such wells would assuredly suffer. It would, therefore, be a distinct injustice to enforce by legislation the exclusion of water in all cases, but if the value of an oil field is ruined by imprudent explorers, some official steps must be taken in the matter.

Portland cement, invented by an English workman, is substantially a mixture of limestone and clay or fine argillaceous matter, calcined by heat, and then pulverized into a fine powder under suitable crushing rolls. Its composition varies, but the active compounds in the mixture are calcium oxide (CaO), silicon dioxide (SiO_2), and oxide of aluminium (Al_2O_3), although it is usually associated with traces of ferric carbonate ($Fe_2(CO_3)_3$), ferric oxide (Fe_2O_3), magnesium oxide (MgO), potassium oxide (K_2O), and sodium oxide (Na_2O).

The hardening may perhaps be simply described as a process of hydration in which water is taken up chemically, as in the slaking of lime, resulting in the formation of hard and insoluble crystalline silicates and aluminates of calcium; though this must be taken as a very incomplete account of what has not been completely elucidated.

A Russian professor, who has been recently investigating the subject of cement, has produced, it is reported, a quick-setting variety by the addition of a small proportion of calcium chloride, but no proper tests have yet been made to ascertain its worth, although it is said that a company has undertaken its manufacture on a large scale.

Baku boring can only be conducted by under-reaming sufficiently to secure absolute freedom for the lining tubes, and, objectionable as the practice is in theory, it cannot be avoided; but nevertheless, from the very starting of a well, precautions should be adopted for the partial exclusion of water that flows down behind the casing in an unrestricted stream, or, at least, for simplifying subsequent measures undertaken with that object. Some engineers make a point of boring without an under-reamer as soon as a bed of stiff clay is reached, and the column of tubes has passed a local average below the preceding shoe, into which bed the shoe is forced or driven as far as it can be with safety. Such a system is only a temporary expedient that tends to mitigate the evil consequences arising from water entering a lower stratum of a porous nature before the upper water-beds are excluded, but such a method is almost sure to fail unless cementing is also carried out before bailing is commenced. In most of the newer Baku districts surface water exists in very large quantities at a depth of 14 to 70 feet, and considerable importance should be attached to its early exclusion from the bore-hole, by endeavouring to carry the first string of casing completely through the water-bearing formation, and driving it firmly into an impermeable formation such as generally underlies such beds. If the first column fails to reach the impervious stratum, it may be worth while sacrificing a second column with the object of shutting off this water which follows the boring in its progress and hides the true character of the strata; but on a property where such a contingency is suspected, the boring should be commenced with an extra large diameter, so that the early stoppage of a second column does not interfere with the ultimate diameter of the well. If the water lies very near to the surface, and even floods the shaft, as happens in some parts of the oil fields, its passage into the well may sometimes be arrested by ramming round the guide casing broken bricks and stones over which is poured a thick solution of cement.

The point at which cementing should be conducted is an important one to decide, as columns of tubes must not be recklessly stopped, but, except in some districts where a single string may be carried to practically any depth, each column must be driven as far as possible if a large diameter well is to be completed. The cementing should not be postponed too long, as in the event of a failure a second operation, deeper, is made more difficult and expensive to perform, but the engineer must exercise his discretion in each separate well and his decision must be guided by the condition of the well, the former results attained, and the estimated depth at which the oil will be struck; for unless the property is a new one he will be acquainted with the approximate positions of the clays, sands, and water-impregnated strata, and may by skilful management be able to stop and drive the various columns of tubes into impervious beds without endangering the final dimensions of the bore-holes.

Other Methods of excluding Water from Bore-holes.—Other systems of shutting off water have from time to time attracted local curiosity in the oil fields, but few have received more than casual attention, although it is not improbable that more extended trials will be made with them in the future. The points where lining tubes are cut out from wells constitute an easy and almost certain inlet for water, and amongst other arrangements tried for the exclusion of water, attempts have been made to secure a water-tight joint at this position. Lead and composition rings have been inserted and firmly driven into the space intervening between two successive columns, but whilst forming a temporary partial remedy, they in no way prevent the passage of water through faultily jointed tubes, and without the addition of some filling material, their employment, except where screwed casing is used, does not ensure success.

The well-known and popular "packers" that are so extensively employed in America, Galicia, and elsewhere, have met with very little favour in the Russian oil fields, notwithstanding periodical attempts to re-introduce them. Taken as a whole, the results obtained by the use of packers in the Baku fields have, with the exception of a few isolated examples, been far from satisfactory, their application causing, in most cases, only a temporary improvement, but, nevertheless, it cannot be denied that they could be employed with fair prospects of success if the correct time and position were chosen for their affixing.

A packer is a device lowered on the lining tubes which swells automatically, or can be caused to expand, by manipulation from the surface, at the correct time to produce a water-tight joint against the sides of the bore-hole or the casing, thus entirely excluding overhead water. A packer recently tested in Baku was formed by binding lengths of loosened Manilla fibre, about 20 feet long, round a tube or combination of tubes of a similar length, by means of twine, at intervals of several feet, the bottom ends being tightly bound to the pipe and all the loose ends carefully cut off, but the upper extremities of the fibres being allowed to extend loosely about a foot beyond the top binding cord. Previous to lowering in the well, the packer is well smeared over with tallow, and when the upper end of the threads has been sunk a few feet below the preceding shoe, the upper loose fringe falls to one side and catches against the shoe as the tubes are forcibly drawn upwards, causing the hempen fibres to slide over the tube to which they are bound, and to be crushed into a bulky mass against the sides of the bore-hole. Lengthy submersion in water leads to swelling of the Manilla strands from absorption, which serves to increase the force with which the packer acts, and where such an arrangement is skilfully fixed on perfect casing, in a compact stratum, all upper water is perfectly excluded. The objection to this class of packer in particular is the liability to disarrangement of the strands of Manilla during descent in another tube where the internal riveting is very imperfectly executed, and a sharp lap-jointed edge is exposed the whole depth.

The elasticity of rubber is frequently made use of in the construction of packers; the expansion being produced either by the direct weight of the column of tubes above it, or by means of a device which causes expansion of the resinous substance when manipulated from the surface. The chief reasons for condemning the application of packers in general in the Baku fields are, the fragile and uncertain nature of most of the strata, the occurrence of oil in loose sands, and the impossibility of foretelling the distance to which a column of tubes will pass. If a packer is to be successful in its object, it must be fixed in ground of a fairly solid, compact character, unlikely to crumble away or cave in, otherwise its presence is useless in a few weeks, and as most of the oil formations are preceded by gas sands or fragile ground, its employment near the oil stratum is generally prohibitive. Were the tubes of better quality, and could the depth to which a column of casing would pass be foretold, the packer could be placed a fixed distance above the shoe and brought into action below the preceding shoe, when the depth of the boring had reached the prearranged point, but unfortunately Baku strata have an objectionable habit of caving when least expected, completely falsifying all prognostications. Boring 100 or 200 feet is not the work of a few days, as in America, and this distance may occupy two or three months, during which period the repeated raising and lowering of the tubes may damage the packer and render it useless. In Grosny, where the strata are not intercepted by beds of running or loose formations, and where neither big plugs nor heavy cavings are usual, the prevailing conditions are peculiarly adapted to the attachment of packers, and where they have been lowered on 2-inch and 4-inch tubes, the wells have, as a result of the confined outlet, either flowed steadily or ejected oil at regular intervals for a long period.

The latest suggestion for the exclusion of water from the oil wells is to freeze the earth surrounding the bore-hole by suitable measures, and a Baku business house has made some arrangements with a specialist in this class of work for conducting some experiments. The plan suggested is to lower into the well a column of casing 4 inches less in diameter than the existing size, and to insert in the space separating the two columns a series of small tubes which are to be kept at a very low temperature by a compressed-air freezing plant operated by a 25 nominal horse-power engine fixed at the surface of the well, and retained exclusively for this purpose. The refrigerating effect would extend well into the strata surrounding the lining tubes, and cause a solid ring of ice to form, which would prevent the passage of all overhead water to the lower oil stratum. Even if the scheme is successful, there are serious objections to its employment, in the expensive nature and upkeep of the refrigerating plant, and the diminution of the diameter of the well by 4 inches, but there is some considerable doubt whether the scheme can be satisfactorily worked in Baku wells, where there is generally a high level of liquid, a constant stream of warm liquid rising in the well as bailing proceeds, and a continuous escape of warm gases, a combination which will require some overcoming.

The subject of exclusion of water cannot be dismissed without mention of the advantages attending the use of screwed casing, which are more particularly enumerated in the chapter on Casing. In the Baku oil fields the frequent landslips and flowing nature of the strata cause the fracture of these expensive tubes almost as frequently as cheap riveted casing, so that proprietors of oil properties do not favour their purchase; but in Grosny these difficulties are not encountered, and the employment of screwed tubes in many of the wells is answerable for the excellent way in which the upper water is usually closed in that field.

Tracing of Subterranean Movements of Water.—The author recently conducted some experiments to trace, if possible, the movements of water that accompany the oil series. For the purpose of the investigations, fluoresceïn, a derivative of phenol, one of the coal-tar products, was employed, but although, when present in ordinary water to the extent of one part in several millions a beautiful fluorescence is produced, no such distinctive tint was developed in well waters. When fluoresceïn was added to Baku water, a brown deposit was formed, due, doubtless, to the combination of soluble aluminates in the water—for such compounds are nearly always present—with the fluoresceïn, and precipitation of the colouring matter. For the above reason the experiments were not altogether satisfactory, although in one or two cases, water removed from wells separated by 100 feet from the bore-hole in which the fluoresceïn was introduced, exhibited a brown deposit which led one to strongly suspect a communication. Further investigation in this subject would well repay the trouble occasioned.

CHAPTER VIII.

METHODS OF RAISING OIL.

Reasons for bailing Baku Wells.—Conditions rendering pumps and similar valvular contrivances useless.

Bailers.—Description of usual Russian form.

Method of Bailing.—Details of arrangement—Bailing tub—Settling tub—Trouble caused by excess of sand.

Bailing Curved Wells.—Use of shorter and smaller bailers—Jointed or flexible bailers—Bailer of flexible metallic tubing—Specific example of its value—Difficulties of construction, and how surmounted.

Accidents to Bailers.—Overrunning, causes, and various devices for prevention.

Recorders or Controllers.—Necessity for continuous bailing—Description of European Petroleum Co.'s recorder—Other advantages besides merely recording work done.

Recovering Lost Bailers and Disconnected Parts left in Wells.—Forms of fishing hooks for recovery of bailers—Recovery of bailer when covered with sand—Recovery or disposal of bailer valve.

Precautions and Economies in Bailers.—Oil brought up on rope—Leakage from bailing tube—Drippings from bailing drum—Means for collection.

Cylinder Pumps.—Damaging effect of even small quantities of sand, and consequent failure at Baku and Grosny—Description of deep-well cylinder pump—Some curious results on experimenting with this class of pump.

The Use of a Packer.—Description and method of use—Sand the usual objection.

Hydraulic Ejector.—Early method applied to water—Principle of action—Apparatus employed—Nagel's patent—Figures relating to results—Unlikely to rival air-lift.

Motive Power on the Oil Fields: Steam-engines.—Steam exclusively used till a few years back—Proved superiority of English engines—Type of engine used—Features in which engines differ from those commonly used in England—Foundations for engines to suit local conditions—Important details to be considered in view of dangers peculiar to the work.

Oil-engines.—General advantages of oil- as compared with steam-engines—Benzine- and crude-oil engines—Supersession of the former by the latter—Principle of Hornsby's successful crude-oil engine—Comparison of steam-engine and oil-engine in regard to simplicity of construction, flexibility in power evolved, liability to repair, and suitability for varying load—Cost per horse-power, need of skilled attendant, ease of removal—Care of oil-engines—Starting device for the Hornsby engine—Description of Hornsby-Akroyd oil-engine—Diesel motor—Advantages claimed—Alleged drawbacks.

Gas-engines.—Used for generating electricity—Details deferred to future chapter.

Power needed for bailing Wells.—Tabular statement—Peculiar action owing to presence of gas in oil contained in bailer—Effect on bailing-engine—Indicator diagram showing this effect.

Electric Power.—How adapted for oil fields—Examples of oil-engines, gas-engines, and steam-engines in the generation of electrical energy—Distribution of current—Motors used at the derricks—Cost now the only serious objection to general employment of electrical power—Some details as to cost.

CHAPTER VIII.

METHODS OF RAISING OIL.

Reasons for bailing Baku Wells.—The oil of the Baku petroleum fields is, almost without exception, struck in beds of loose flowing sands, having, when free from water, the appearance of fresh *caviar*, and it is not an uncommon occurrence, in a new well, to meet with a constantly rising plug exceeding 500 feet in depth, which has to be patiently cleaned for weeks or months, during which time only a nominal output of oil is obtained. Pumps and other contrivances, of which small valves form an essential part, are rendered useless in the presence of such volumes of sand, and a substitute has been found in bailers.

Bailers.—A bailer is a long, cylindrical vessel manufactured from light sheet-iron, fitted with an interchangeable cast-iron valve and seating at its lower extremity. It is constructed by connecting together a sufficient number of sheet-iron sleeves, 4–7 feet long, that are riveted together to produce the desired length, and afterwards soldered to ensure perfect water-tightness. A safety rod made of ⅜-inch round iron extends the full length of the interior of the bailer, and is secured by a cross-bar at each extremity, its attachment being merely a precautionary measure to prevent loss of part of the bailer in case the joints were torn asunder. The usual Russian form is illustrated in Fig. 53, and the slightly tapered shape given to the top and bottom lengths serves simply as a guide to the bailer and a protection to the valve and suspension hook. The diameter and length of the bailer are determined by the size and character of the wells, and they vary from 4 inches to 14 inches in diameter, and in length from 7 feet to 45 feet. Table XIX. gives the capacities per foot in poods of oil, and water, for different-sized bailers.

TABLE XIX.

GIVING THE CAPACITIES OF BAILERS IN POODS OF OIL AND WATER PER FOOT OF LENGTH, FROM 3 INCHES TO 14 INCHES DIAMETER.

(Oil = 54 lbs. (English) per cubic foot; well-water = 65 lbs. (English) per cubic foot.)

Diameter.	Capacity per foot in poods.		Diameter.	Capacity per foot in poods.	
	Oil.	Water.		Oil.	Water.
Inches.			Inches.		
3	0·07	0·08	9	0·66	0·79
4	0·13	0·16	10	0·82	0·98
5	0·20	0·25	11	0·98	1·17
6	0·29	0·35	12	1·18	1·41
7	0·40	0·48	13	1·38	1·65
8	0·52	0·63	14	1·60	1·92

Method of Bailing.—Bailing is performed by means of a light winding drum fixed in the derrick, driven by a motor through the medium of a belt, or coupled up direct to the motive power by gearing, both of which systems have their adherents, and possess their own special advantages, but the belt-driven type is in most favour.

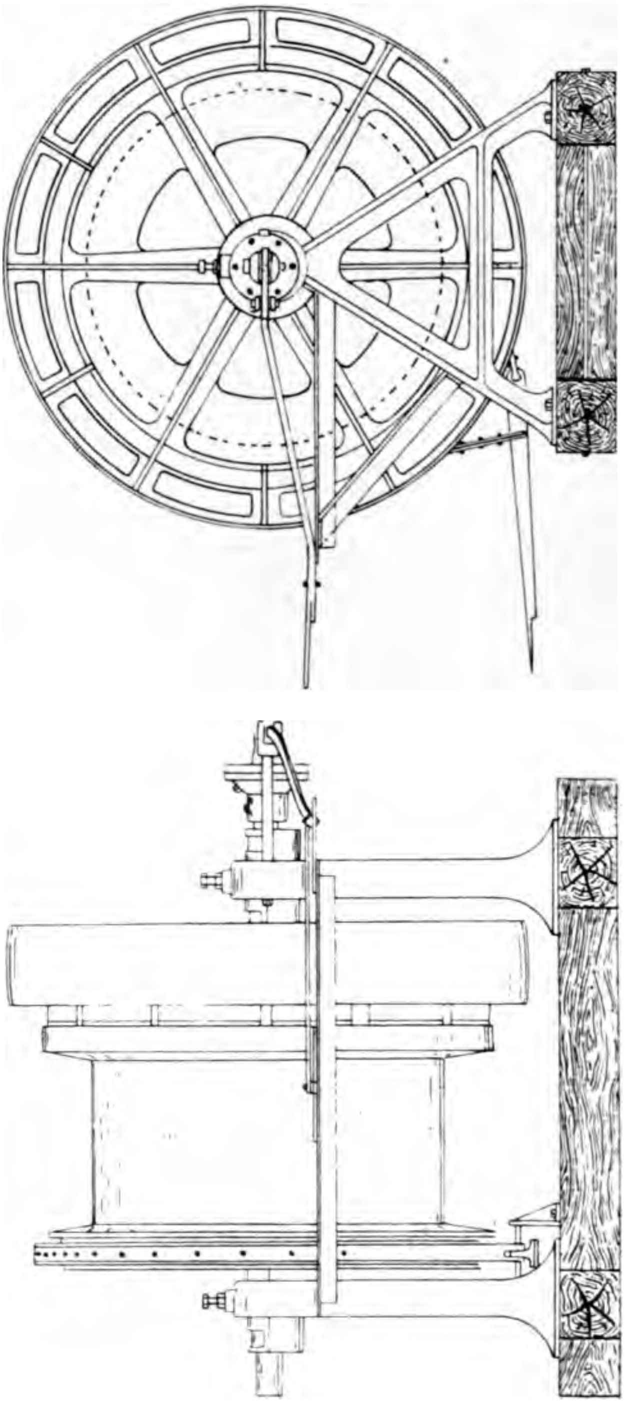

Fig. 50.—Eisenschmidt's Extra Large Bailing Drum of Latest Design.

(16-feet circumference drum.)

Fig. 50 shows a 16-feet circumference bailing drum manufactured by Messrs. Eisenschmidt, of Baku; and Fig. 51 illustrates a 13-feet circumference bailing drum, of special design, made by the Votan Co., Balakhany.

A wire rope is wound on to the drum, and the free end is led over a 4-feet or 5-feet grooved pulley, situated at the top of the derrick, so as to hang vertically over the centre of the well, and from this rope the bailer is suspended by the use of a shackle. On the floor of the derrick, immediately over the mouth of the bore-hole, and slightly raised on trestles, is placed what is locally termed a bailing tub, consisting of a wooden tank into which the liquid from the bailer flows. The bailing tub is an ordinary circular or square vessel about 6 or 7 feet in diameter and 5 feet high, with a perforation in the base through which the bailer can pass, and on one side of the tub is cut an outlet leading into a chute by which the product runs away. The bailing tub is so arranged that when the full bailer has been raised from the well, a flat disc with a sheet-iron or copper surface can be pushed over the mouth of the orifice the moment the bucket has emerged, by means of an iron or wooden rod extending to the operator of the drum. When the bucket is lowered gently by the aid of the brake with which the drum is supplied, the valve opens inwards by reason of the whole weight of the bailer and oil falling on the guide spindle, and the fluid runs away, its return to the well being prevented by arranging the before-mentioned sliding door about 1 foot above the floor of the tub, whilst the outlet lies at the base.

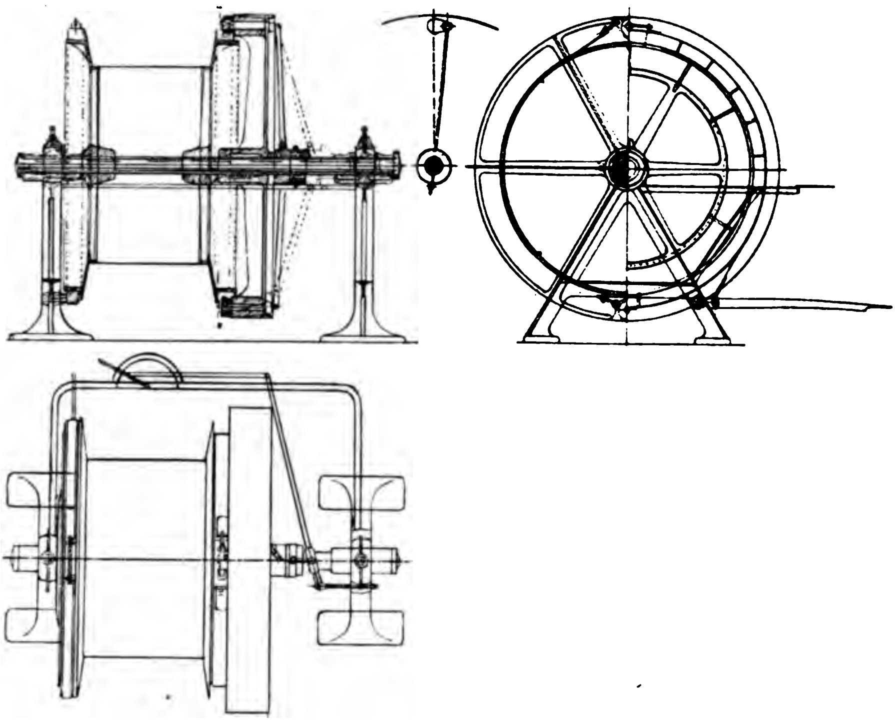

Fig. 51.—Votan Company's Ordinary Bailing Drum.
(13-feet circumference drum.)

Fig. 52, of the well in working order, gives a clear idea of the arrangement almost universally adopted where bailing is employed.

From the well the oil is conducted in chutes to a series of wooden settling tubs about 12 feet in diameter and 4 feet deep, where the sand is deposited, and from which the clear oil is diverted into channels connected with storage tanks.

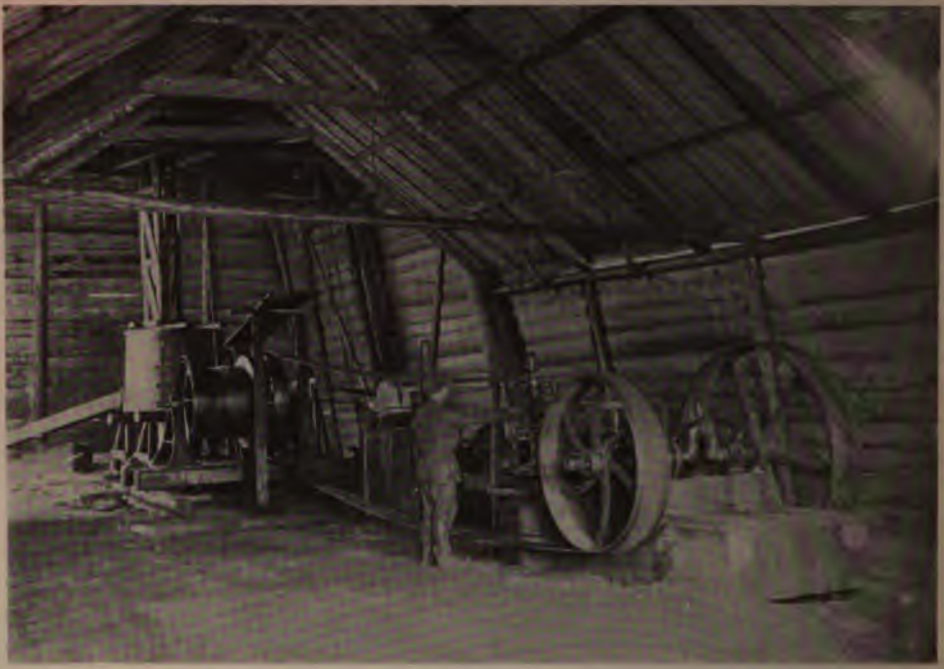

Fig. 52.—Showing General Arrangements of a Bailing Well in the Russian Oil Fields.

Tables XX. and XXI. give the capacities of oil in poods per foot and inches of depth, and per foot and decimal parts of a foot of different-sized settling tubs from 6 feet to 15 feet in diameter. The tables have been prepared to facilitate calculations, as the output from wells is frequently measured in the settling tubs.

TABLE XX.

GIVING THE CAPACITIES OF SETTLING TUBS IN POODS OF OIL PER FOOT OF DEPTH, FROM 6 FEET DIAMETER, INCREASING BY INCHES TO 15 FEET DIAMETER.

(1 cubic foot of oil = 54 lbs. English, or 60 lbs. Russian.)

Diam.	0	1 in.	2 ins.	3 ins.	4 ins.	5 ins.	6 ins.	7 ins.	8 ins.	9 ins.	10 ins.	11 ins.	Diam.
Ft.													Ft.
6	42·41	43·60	44·80	46·02	47·25	48·56	49·77	51·06	52·36	53·68	55·01	56·36	6
7	57·73	59·11	60·51	61·92	63·35	64·80	66·27	67·75	69·24	70·76	72·30	73·83	7
8	75·40	77·98	78·57	80·18	81·81	83·46	85·12	86·79	88·49	90·20	91·92	93·67	8
9	95·43	97·20	98·99	100·80	102·62	104·47	106·32	108·19	110·08	111·99	113·91	115·85	9
10	117·81	119·78	121·77	123·77	125·79	127·83	129·88	131·95	134·04	136·14	138·26	140·40	10
11	142·55	144·72	146·90	149·10	151·32	153·55	155·80	158·07	160·35	162·65	164·96	167·30	11
12	169·65	172·01	174·39	176·79	179·20	181·63	184·07	186·54	189·02	191·51	194·03	196·55	12
13	199·10	201·66	204·24	206·83	209·44	212·06	214·71	217·37	220·04	222·73	225·44	228·17	13
14	230·91	233·66	236·44	239·23	242·03	244·86	247·70	250·55	253·42	256·36	259·21	262·13	14
15	265·07												15

When a rich oil source is encountered, the sand which first puts in an appearance is so fluid in character that the bailer can be raised full, and still the mixture will run with moderate freedom in the inclined chutes. The quantity of sand raised in this manner is sometimes so great that the services of eight or ten workmen are required to clear away the accumulations which collect around the derrick, and it is on this account that, when fixing the position of new wells, the derrick should be built upon an embankment from 10–20 feet high, made of sand excavated from the base, as reservoirs, or so-called *ambars*, are thereby formed where the *débris* during boring, and the subsequent sand whilst bailing, may be deposited. Lack of foresight in arranging plenty of ambar space leads to considerable inconvenience and confusion on properties at a later date, and careful consideration should be given to this subject whenever new wells are laid out.

TABLE XXI.

GIVING THE CAPACITIES OF SETTLING TUBS IN POODS OF OIL PER FOOT OF DEPTH, FROM 6 FEET DIAMETER, INCREASING BY TENTHS TO 15 FEET DIAMETER.

(1 cubic foot of oil = 54 lbs. English, or 60 lbs. Russian.)

Diam.	0	0·1 ft.	0·2 ft.	0·3 ft.	0·4 ft.	0·5 ft.	0·6 ft.	0·7 ft.	0·8 ft.	0·9 ft.	Diam.
Ft.											Ft.
6	42·41	43·84	45·28	46·76	48·25	49·77	51·32	52·88	54·47	56·09	6
7	57·73	59·39	61·07	62·78	64·51	66·27	68·05	69·85	71·67	73·52	7
8	75·40	77·29	79·21	81·16	83·13	85·12	87·13	89·17	91·23	93·32	8
9	95·43	97·56	99·70	101·89	104·10	106·32	108·57	110·85	113·14	115·46	9
10	117·81	120·17	122 57	124·98	127·42	129·88	132·37	134·88	137·41	139·97	10
11	142·55	145·15	147·78	150·43	153·10	155·80	158·52	161·27	164·04	166·83	11
12	169·65	172·48	175·35	178·23	181·14	184·07	187·03	190·02	193·02	196·03	12
13	199·10	202·17	205·27	208·39	211·54	214·71	217·90	221·12	224·36	227·60	13
14	230·91	234·22	237·55	240·91	244·29	247·70	251·12	254·57	258·05	261·55	14
15	265·07										15

Bailing Curved Wells.—The number of deflected wells in some districts is very great, and they have a most damaging effect upon all bailers. If a well from some cause is not vertical, the defect is made apparent by the damage long bailers sustain in their descent into the well; but where the diameter of the well is large, the difficulty may be overcome by using a shorter or a smaller bailer, or a bailer combining both qualities. The curvature of the well may, however, be so great that it will not admit of the passage of any straight bailer of sufficient capacity to make the well payable, in which case a jointed bailer is constructed to meet the exigency.

A jointed or flexible bailer is an ordinary bailer divided into two or three sections (according to the deflection of the well where it will be employed), each of which is connected to the preceding one by a common knuckle joint, a passage being left for the oil to pass freely through the centre of the joint. By the use of jointed bailers, wells, otherwise unprofitable, may be brought into active exploitation, and many examples of large producing wells bailed in this manner could be quoted (see 2, Fig. 53).

An ingenious application of the English, flexible, metallic tubing has recently received much attention, and it has been proved to be very valuable for bailing excessively crooked wells, where even the common flexible bailers are used with difficulty. In the case of any curved wells, the destruction of bailers is very great, and constant repairs are needed to repair the damage caused by the friction against the sides of the well casing; but this abrasion on flexible-tube bailers may be minimized by soldering thin sheet-iron rings to the tubing at intervals of a few feet, which do not impair the flexibility to any appreciable extent, but effectually protect their surfaces from wear. By the employment of flexible metallic bailers, bailing may be continued in wells otherwise useless, and the extra cost, which is heavy, is scarcely to be considered when such results may be obtained. The author, by their use, has succeeded in bailing a crooked well with an 8-inch flexible metallic-tube bailer 35 feet long, where by using a three-jointed bailer of the old fashion only a 6-inch by 21-feet bailer would pass, and this had to be changed for repairs many times a day. These flexible bailers will work under very bad conditions for two or three months, and effect a considerable economy by working continuously for several weeks without any stoppage for changing or repairing; but after this time the repeated bending and unbending wears the joints of the spirals, which begin to leak, and they soon develop a tendency to untwist, and ultimately break.

Flexible metallic tubing of 6–10 inches diameter can only be purchased in limited lengths, owing to practical difficulties in its manufacture, and if 5- or 6-sagene bailers are needed, two or more lengths must be connected. The junction of two lengths is made by means of a wrought-iron collar, upon each end of which is cut a thread corresponding to the spirals of the tubing, into which the latter is firmly screwed, being afterwards additionally strengthened and rendered water-tight by soldering. It is found in practice that unless vertical guides are placed above the bailing tub, when these bailers are used, they will coil up so much on emptying that it is difficult to direct them back into the well. Fig. 53 shows the different forms of bailers, from which their construction will be intelligible.

Accidents to Bailers.—One of the chief accidents in bailing wells, and one of almost constant recurrence, is the drawing of bailers over the top bailing pulley, where they are flattened out completely or torn to pieces. Such an occurrence may be due to a faulty or greasy brake on the bailing drum, wedging of the friction blocks, or, as is more frequently the case, the negligence of the bailing man. Numerous devices have been suggested and patented for the prevention of overrunning, but most of them are cumbersome, expensive, or irregular in their work, and few firms have gone to the expense of erecting any special devices for dealing with the problem. The loss lies not only in the damage to the bailer, but in the long stoppage required to remove it, or cut it away from the overhead pulley, especially if the accident occurs at night, or on a cold and windy day, when the work of removal is very dangerous, if not impossible. The bailers are sometimes drawn up with such force that they pass completely over the pulley, and are flung in a mangled condition with considerable violence on to the roof of the engine-shed.

The principle of most of the systems suggested to prevent overrunning is to shut off steam and disengage the friction wheel, or apply the brake to the drum automatically, when the bailer has passed beyond a certain fixed point in the derrick, from which it can afterwards be removed without serious damage, or released by cords from the floor. Perhaps as simple and effective a plan as any is to fix two stout timbers across the derrick a little below the bailing pulley, leaving only an orifice of sufficient area to freely admit the bailing rope. The severe shock of an overdrawn bailer may cause the wire rope to break, and lead to the fall of the bailer into the tub; but this is cheaper and preferable to the delay and inconvenience of working many hours overhead.

Bailing drums have recently been introduced which automatically apply the brake when the bailer reaches a fixed point in the derrick, if the operator through negligence should allow the bailer to overshoot the mark. These drums perform their work satisfactorily when new, but they lead to more complicated attachments and more intricate parts liable to get out of order, which it is better to avoid wherever possible.

Recorders or Controllers.—The bailing of wells is carried on uninterruptedly day and night, as the stoppage of only a few hours, besides leading to a pecuniary loss, often causes damage to the well through the accumulation of water or the formation of a

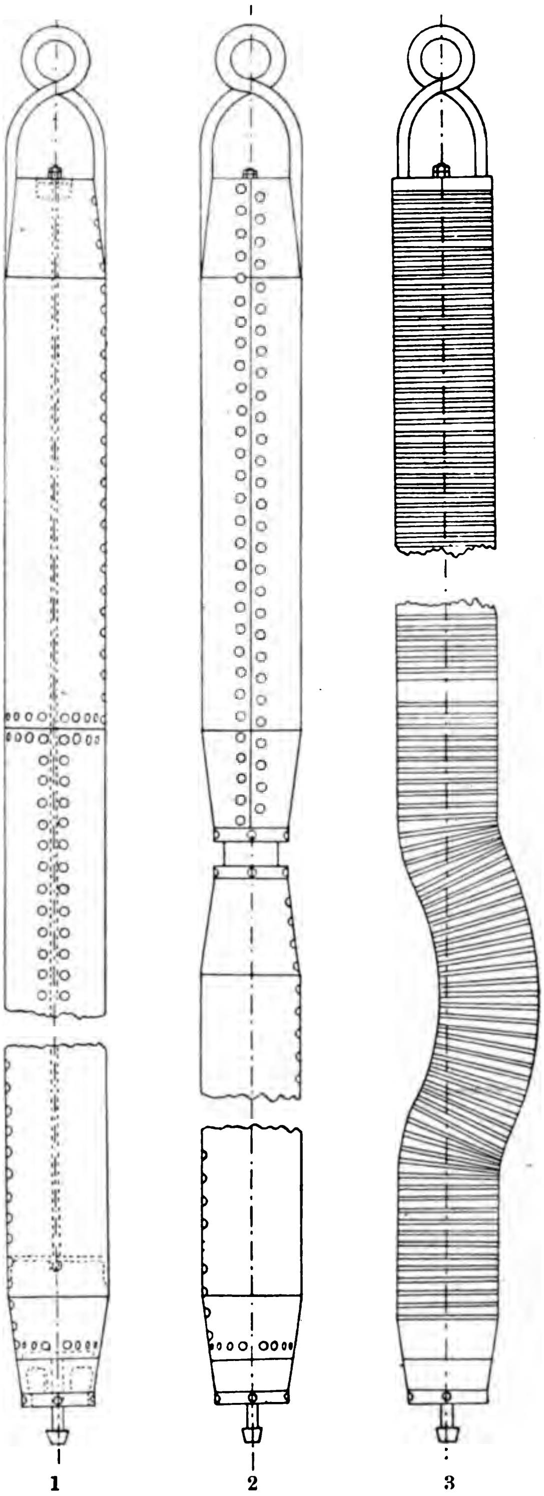

Fig. 53.—Types of Bailers.

1. Common straight form of bailer.
2. Jointed bailer, for curved wells.
3. Flexible metallic tube bailer for excessively deflected wells.

hard plug. In order to keep a check on the bailing, especially at night, when the supervision is less, several arrangements have been devised for recording accurately the work performed. A simple recorder, designed by the European Petroleum Co., consists of a spindle, which may be attached by a flexible joint to the shaft of the bailing drum, actuating at right angles a second spindle, which in turn gives motion to a pencil pressing against a prepared paper coiled on a small barrel. This barrel is revolved by clockwork placed internally, so that one revolution is completed in 12 or 24 hours; thus causing a complete record of the work to be marked on the sheet of paper. The illustration (Fig. 54) shows a diagram taken from such a recorder, where the vertical pencil-lines show the number of trips of the bailer, the depth to which they were made, and the number and duration of any stoppages, whilst the vertical

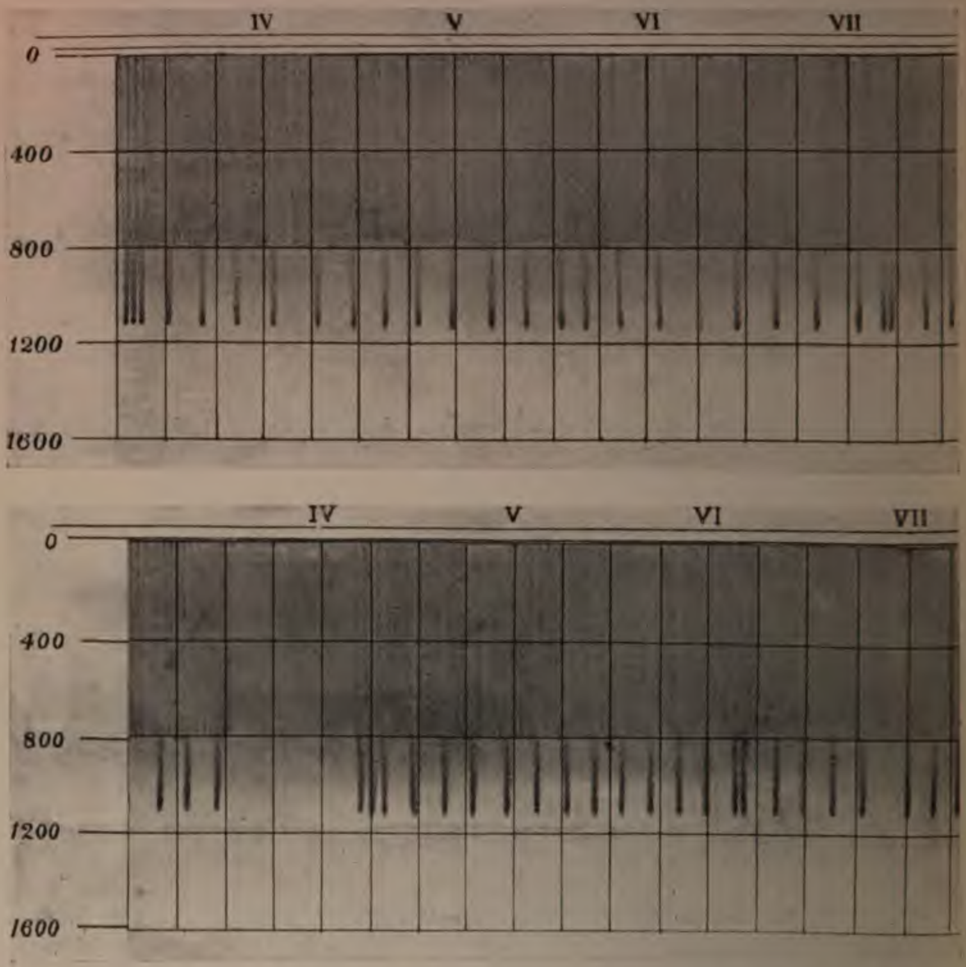

Fig. 54.—Diagrams from Recorder attached to Bailing Drum bailing a Baku Oil Well.
Vertical lines represent hours and quarter-hours. Horizontal lines represent feet.

ink divisions and subdivisions mark off the hours and portions of an hour. This recorder is also fitted with two gongs, which can be set to strike at any depth of the bailer; the object of the first being to notify the attendant when the bailer is approaching the liquid, so that the brake can be applied and the bucket can be lowered gently into the oil; the second to call the operator's attention when the bailer is emerging from the well, to prevent overrunning through negligence. By the use of such controllers a very accurate record of the bailing is obtained, and besides showing exactly the number of bailers taken from the bottom and the top of the liquid,* the fluctuations of level are exhibited by the length of the lines corresponding to the top bailings.

Other recorders are obtainable, some of which are extremely complicated, but few produce such an accurate record of the work performed as the above device.

Recovering Lost Bailers and Disconnected Parts left in Wells.— Bailers, or parts of bailers, are frequently lost in the oil wells through a variety of causes; in fact, fishing for their recovery is a daily operation on all large properties. The bolt of the shackle connecting the wire rope to the bailer may break or work loose and fall out, and to prevent this the bolt should always be screwed into one end of the shackle, and be additionally provided with a nut or split pin on the protruding end. The rope itself may break, or the bailer may separate or be torn asunder, and part remain in the well. Sometimes the suspension hook strips from the bailer, and at other times bailers are dropped through some carelessness or accident at the surface; occasionally, too, the rope entirely unwinds from the drum, and descends into the bore-hole. Bailer valves often become loose unobserved, unscrew and remain in the well, and very frequently the guide spindle of the valve breaks off.

In most cases there is not much difficulty experienced in recovering the bailers, and for the purpose an assortment of different-sized fishing hooks is kept handy on the property. If the shackle bolt unscrews or breaks, or the rope separates immediately above the shackle, a two-, three-, or four-pronged fishing hook (as shown in Fig. 55) is lowered on a wire rope, and rarely fails to secure a firm hold on the first trip. If the suspension hook of the bailer is detached, or is broken, or the bailer has parted, then one of the other forms of hooks must be employed, which are heavy iron rods provided with two or more "dogs" or "fingers" that work loosely on a joint. When being lowered they pass freely through even a confined space, but on being raised the dogs fall and extend horizontally, thus firmly gripping the sides of the bailer. A collection of "dogs" is kept in stock to suit different sizes of bailers, so that there need be very little delay before commencing to fish.

With this form of fishing hook it is always advisable to use guides to keep the rod central and ensure its passage into the mouth of the bailer, otherwise the hook may sink to one side, and take a powerful hold between the bailer and the well casing, and give much trouble to remove it.

At times the sand, held in suspension by the evolution of gas and consequent agitation of the fluid during bailing, settles on and around a lost bailer before

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* For explanation of top and bottom bailing, see Chapter X.

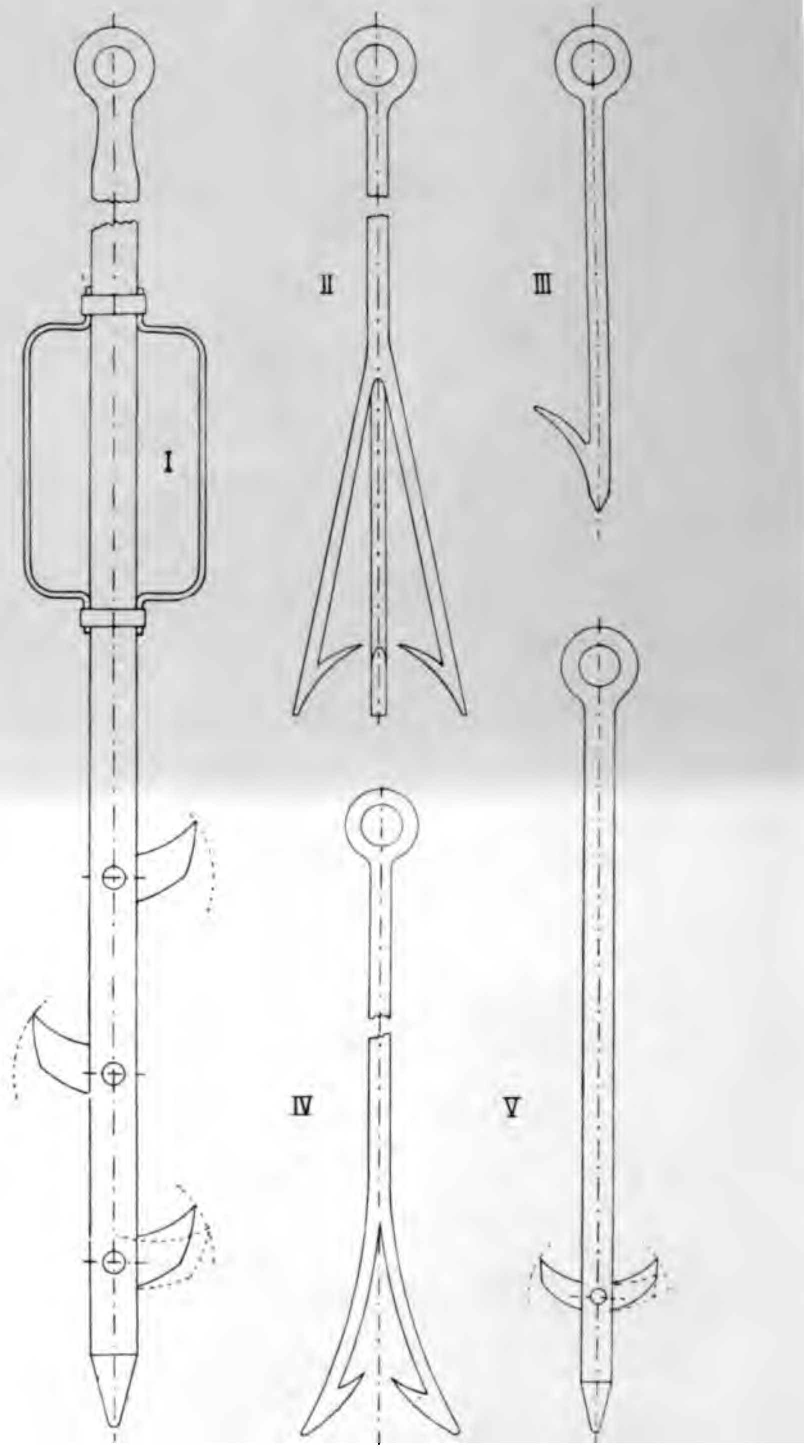

Fig. 55.—Hooks for recovering Lost Bailers and Wire Ropes.
I., V. Hooks for recovering bailers when the suspension hook is broken.
II., III., IV. Hooks for recovering lost bailer or wire rope.

it can be removed, and holds it very firmly, in which case $1\frac{1}{4}$-inch rods, with a powerful hook attached, must be lowered by means of a pulley-block operated from the bailing drum, and then power applied; but if it is not then freed with the application of a reasonable force, washing tubes must be lowered, and the sand swilled away by a flow of water.

When a bailer valve is lost in a well, a pair of self-acting tongs is lowered on the ordinary wire rope, the jaws of the tongs being kept extended by a special device until the bottom is reached, but on touching the ground a link is released automatically, and the claws close and fasten upon any object between them immediately the tongs are raised. If the tongs fail to raise a lost valve after a few trials, the simplest plan is to smash it up (as it is only cast-iron) by means of a heavy sharp-pointed pick, and raise the cast-iron fragments in an ordinary American bucket; but usually the loss of such a small article is a matter of no importance, and the valve disappears in the loose sand after a short time.

Precautions and Economies in Bailing.—In bailing wells where there is a high level of liquid, a great quantity of oil clings to the wire rope after passage through the oil, and when bailing is conducted at a high speed, a heavy spray is discharged tangentially from the rope at the point where it commences to curve over the bailing pulley, *i.e.*, the point where its vertical direction is deflected. If the pulley is unprotected, the oil is blown about to such an extent that everything near becomes saturated with oil, which, besides being a source of danger, turns the property into a quagmire. The nuisance may be prevented, and the oil, which may amount to a hundred poods a day, saved, by placing a wooden or sheet-iron guard over the pulley, and fixing a wooden chute between the drum and the bailing pulley for the rope to run in. The oil from the rope, leakages from the bailing tub, and drainings from the bailing drum, amount altogether, in a high-level well, to several hundred poods a day, and instead of allowing the oil to sink into the ground and be lost, as is usual, a wooden floor should be constructed with an incline towards one end, where the drainings collect in a chute leading to a collecting tub.

Cylinder Pumps.—When an oil well has been bailed for some months, the quantity of sand diminishes, and, in some cases, is very small in amount, and many attempts have been made to supply another and more reliable, or automatic system of raising the oil. All experiments with deep-well cylinder pumps have turned out failures in the Baku oil fields, for even the minute quantity of sand always present in the oil renders them useless for all practical purposes. Even in Grosny, where the sand is almost imperceptible in quantity, failure has, up till now, attended all endeavours to utilize them.

A deep-well cylinder pump consists of a long, accurately bored barrel or cylinder, at the lower end of which is screwed a socket to which is connected the suction-pipe. The socket is bored with a slightly tapered hole, the larger end uppermost, and acts as a seating for the suction or retaining valve. The plunger of the pump is designed to hold from three to six cup-leathers, which form a very secure piston when the pressure of the column of liquid overhead forces open the cups and causes them to press firmly against the sides of the cylinder. In the centre of the plunger is fitted a ball valve, which lifts upwards when the plunger sinks, and allows the liquid to pass through, but closes on the piston being raised, and lifts the fluid enclosed in the vessel above it. The pump-barrel is lowered into the well on tubes a little larger in diameter than the internal dimension of the cylinder, and 10 to 25 feet of suction-pipe may be fixed below the pump, with a strainer at the bottom. When the desired depth is reached, the tubes are fixed with pipe-clamps, and the plunger is lowered on spear-rods to the same point, great care being taken to ascertain exactly the point when the bottom is reached. The best spear-rods are Canadian pole-tool rods, or wooden rods with screwed iron ends, as a portion of the weight is supported by the fluid in which they are immersed; but 1-inch or 1¼-inch steam tubing may be used for the purpose, and even ¾-inch wire rope has been employed for temporary work, although the former is liable to fracture as the result of the vibration, and the latter makes it necessary to use correct judgment to allow for the stretch in the rope during work. Motion is transmitted to the spear-rods either by a crank or by a walking beam at the surface, and if the weight of the spear-rods is accurately balanced by a counterpoise, very little power is required. If it is essential that the oil should be pumped to a distance, direct from the well, or to a height above the floor of the derrick, a stuffing-box and gland must be attached to the surface, but otherwise a T-piece may be inserted in the rising main at the surface and the oil allowed to flow away by gravitation in chutes or pipes.

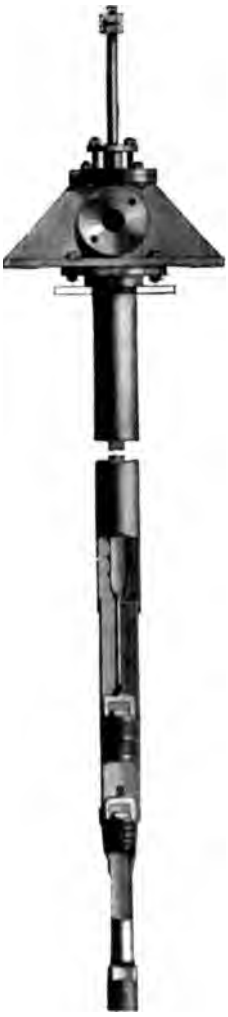

Fig. 56.—Deep-Well Cylinder Pump, made by Messrs. Duke & Ockenden, London.

Experience has shown that when cup-leathers are fitted to the plunger they quickly wear out; metallic pistons last longer, but these also are cut to such an extent, after a time, that the action of the pump ceases. If the pump is stopped for only a short time, the sand suspended in the column of oil, settles upon the valves and chokes them, and the pump cannot be restarted; in fact, in several instances 2 or 3 feet of sand were found to have accumulated above the plunger after a short stoppage, necessitating the removal of all the tubes. There are, perhaps, isolated examples of oil wells where a pump could with advantage be worked if persevered with; but there is no doubt that such wells are few, and there is little chance of any extensive use of pumps being made in the Baku fields.

Some curious results were obtained by the author when recently conducting some investigations with this class of pump. A 2½-inch by 3 feet 6 inch cylinder pump was lowered into a well 215 sagenes (1505 feet) deep and 10 inches diameter, where the level of liquid stood, on an average, 140 sagenes (980 feet) from the surface. The gas was strong, but the quantity of sand, as a rule, was not large, yet nevertheless the damage was so rapid that the pumps could never be kept working more than 24 hours consecutively. The special peculiarity lay in the fact that the discharges were in no way connected with the strokes of the plunger, but were intermittent and of comparatively long duration. The agitation of the oil (supersaturated with gas) by the motion of the piston and spear-rods apparently released the gas and produced a miniature fountain, which lasted several minutes without intermission, and concluded by a violent outburst of gas, after which a period of quiescence followed of 5–10 minutes' duration before a repetition.

When the pump was in good condition and working in the manner described, the rate of output of oil exceeded 3500 poods a day, from a well where the maximum quantity bailed, under the most favourable conditions, was previously and subsequently 2000 poods daily. After experiments extending over a month, the pump was abandoned, as it had to be removed every alternate day for new cup-leathers or metal plunger.

In some trials at Bibi-Eibat, in wells of small diameter, a cylinder pump was made to work for a week at a time without repairs, by the attachment of a metal plunger, but these were in old wells exceptionally free from sand, and this period of work probably represents an "optimum" of local attainments. There are other instances of pumps which have worked for several days with great success, doubling or trebling the bailing output, but so far no practical use on a large scale has been made of them.

The latest introduction is the air-lift process of raising oil, which is such an important and interesting subject that a special chapter is devoted to its description (see Chapter IX.).

The Use of a Packer.—Another method which has been tried from time to time to raise oil is to control the natural petroleum gas exuding from the source and use it to perform the operation of lifting the oil unassisted. A string of 3-inch or 4-inch tubes, fitted with an expanding disc or packer about 30 or 40 feet from the bottom, is lowered in the well; the disc swells automatically when solid ground is struck, or it is manipulated from the surface to produce a firm contact and gas-tight connection against the sides of the casing, the whole of the liberated gas being thus diverted through the smaller tubes. The passage of a large volume of gas through a confined space lightens the column of oil and leads to a steady flow or an intermittent discharge at the surface. It is reported that one well in the Saboontchy area was made to flow continuously for 12 months by this means, and certainly in America great use is made of the natural gas pressure to induce a flow of oil from partly exhausted wells. The chief objection to the use of such a device in the Baku oil fields is the presence of sand, which almost invariably rises and chokes the tubes, preventing further action; but in Grosny, where sand is almost absent, packers have been used with great success, and wells fitted in this way have been made to yield a steady or intermittent flow for a long time.

Hydraulic Ejector.—One or two attempts have been made to apply to oil an old-fashioned method of raising water from deep wells, the principle of which is based on the velocity of a jet discharging into a confined space. Tubes are lowered to a suitable depth in the liquid—in Baku they must reach to the bottom—and into a low point is led a vertically upturned nozzle connected with a separate external pipe that conducts a stream of water at a pressure of from 100 to 120 atmospheres. The high velocity of the vertical jet creates a partial vacuum beneath the nozzle, which causes liquid to rise and commingle with the water and be discharged at the surface. Mr. Nagel, a Russian engineer, has recently patented a modification of the usual ejector, and has had a plant in operation on the Balakhany oil field which has excited some interest, chiefly on account of the claims made by the patentee. In this particular experiment a high-pressure duplex steam-pump transmitted to the water the required pressure of 120 atmospheres, which was led to the ejector in the well through a 2-inch main and expelled into a 3-inch uptake pipe. It was difficult to check the actual level and depth of the well, but it was stated to have a depth of 980 feet, and a level, when standing idle, of 300 to 400 feet from the surface; the ejector was said to be not deeply immersed in the fluid, and the patentee claimed to be able to work his plant with 15 feet of suction. 730 vedros (1971 gallons) of water were pumped down per hour, and 1520 vedros (4104 gallons) were ejected at the surface, so that about double the amount of liquid was raised that was employed in the work. As the total efficiency of the plant did not exceed 7 per cent., under what was presumed to be the best conditions, it does not seem likely that it will be a rival to the air-lift. About 2½ per cent. of oil was abstracted from the expelled liquid, or 5 per cent. from the water actually removed from the well.

MOTIVE POWER ON THE OIL FIELDS.

Steam-engines.—Until a few years ago the motive power on the oil fields was entirely supplied by steam-engines, chiefly of the horizontal double-cylinder type, and for the most part of foreign manufacture; in fact, these engines have been supplied in great quantities by the English firms of Robey, Ruston and Proctor, and Tangyes, who have practically enjoyed a monopoly in this branch of trade. Notwithstanding the keen competition of Russian and German manufacturers, the English engines not only hold their own in the matter of price, after payment of a heavy import duty, but they still retain undisputed their character of being the best engines for local requirements.

The low steam pressure usually employed (60 lbs. per square inch) necessitates the use of very large cylinders to develop the requisite horse-power for bailing purposes, and even then there is no attempt to economize fuel by working expansively, for the cut-off is generally at two-thirds or three-fourths of the stroke. The dimensions of the common class of double-cylinder engines in use are 12-inch cylinder × 16-inch stroke, and 14-inch or 14½-inch × 18-inch stroke, termed respectively 25 and 35 nominal horse-power, but the actual indicated horse-powers obtained in practice are two or three times the nominal.

The chief features in which these engines differ from those used for ordinary purposes in England are: reduced weight, to lessen the duty and freight; less finish to all parts than would be passed for home markets; absence of a governor, which is replaced by a combined equilibrium and stop-valve to permit the engine to be started by a cord from a distance, with the application of a slight pull; and special provision for the separation of water by the attachment of xtra large relief valves to the drain-cocks of the cylinders, and sometimes to he steam-chest. Fly-wheels and pulleys are locally procured, as they add reatly to the cost of importing, and can be obtained on the oil fields, at a easonable price, from small firms who undertake moulding. A 12-inch × 6-inch double-cylinder horizontal engine with fly-wheel and pulley costs 2500

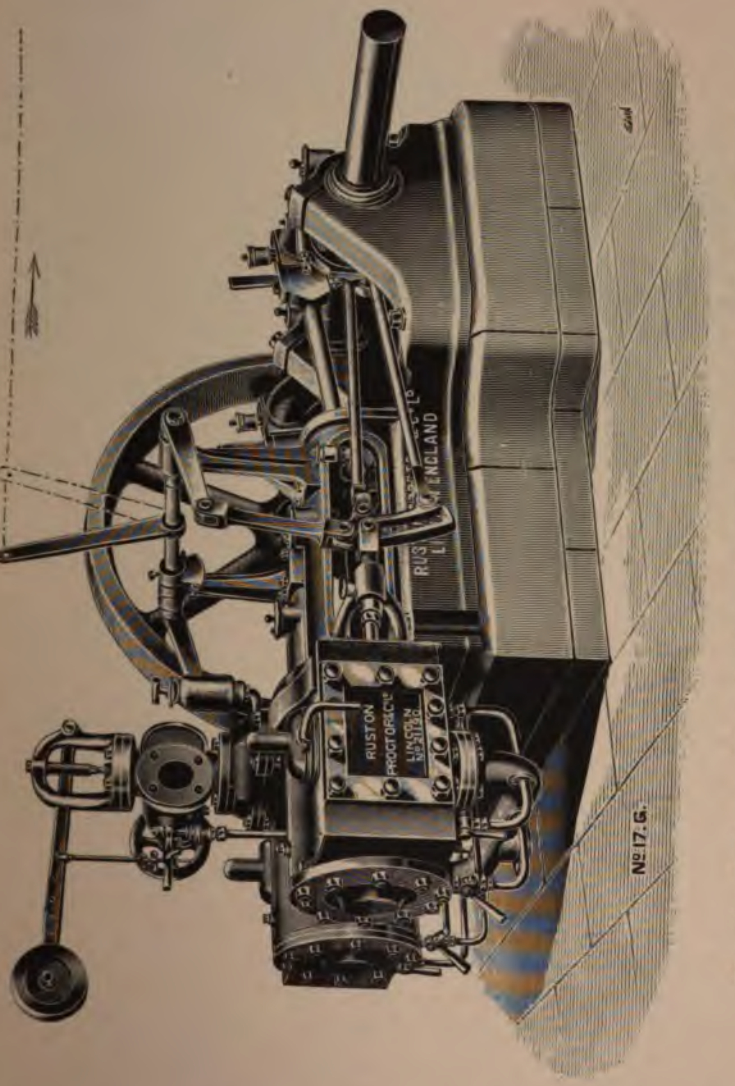

Fig. 57.—Ruston and Proctor Steam-engine, as used in the Russian Oil Fields for boring and bailing Wells.

(For bailing, reversing gear omitted.)

oubles, and a 14-inch × 18-inch or $14\frac{1}{4}$-inch × 18-inch one costs 3000 roubles, ith lubricators and set of wrenches. A German firm some years ago imported ome compound engines of a type very similar to those in work, and it is eedless to add that with such low pressures and the absence of a condenser he results were far from satisfactory, and the experiment was never repeated.

Tangyes' horizontal single-cylinder engines found a ready market at one time, as that class was much in demand for bailing purposes when the wells were shallow and small, but with the exception of one or two firms who employ geared bailing drums, no one now erects single-cylinder engines in the Baku oil fields. In Grosny a more extended use is made of them, but the work is very light compared with Baku, and where they are extensively used a higher steam pressure is employed.

The foundations for the steam-engines are nearly always constructed of timber, because it forms the cheapest and quickest-made base that can be locally prepared, it can be removed inexpensively to another position, and it produces the firmest bed procurable at a moderate cost in the loose surface sand in which it usually has to be fixed. After excavating to a suitable depth, two large baulks are made to lie about 6 feet apart, and parallel with the length of the engine-shed, upon which are placed two cross-timbers within a few feet of their extremities. Two more baulks are then lowered on to the cross-timbers parallel to the first two, and the whole of the timbers are connected by bolts at the points of intersection. Upon the upper couple is then fixed a flat table constructed from planed timbers which receives the bed of the engine, the foundation bolts passing through the cast-iron engine bed-plate, the table, and the lower baulks also where such is possible.

The oil drainings from the engine collect beneath the bed, and form, after a time, a very slippery surface upon the wooden table to which the engine bed-plate is bolted, and the engine is very liable to get loose and slacken the foundation bolts to such an extent that it is impossible to firmly secure the engine again. This tendency may be avoided by sinking the engine bed-plate 1 or 2 inches into the wooden table.

A few companies erect masonry foundations for their engines, chiefly on account of the reduced damage from fire following a conflagration; but unless this is done at a well whose permanence is moderately assured, it is an expensive system, and a practice hardly to be recommended. If too much woodwork is not left exposed, and sand is placed over the timber above ground, the damage from fire is very small, being usually confined to the destruction of all the brass lubricators and joints, so that little more than a thorough clean-up is needed.

The engineer, when purchasing engines for bailing purposes, should never limit himself to an engine of the bare strength required, but should always allow a reserve of power, for if a surplus exists, a larger pulley may be fixed, and the speed of the engine decreased, if the bailing speed is fast enough, when the reduced wear and tear will soon repay the cost of the extra pulley. When the liquid has fallen in a well, or the quantity of sand has diminished, the bailing drum may often be driven direct from the fly-wheel of the engine, and either the velocity of the bailing be increased or the piston speed of the engine reduced.

The following details should be noted by buyers and makers of steam-engines for oil property work: Absence of all white metal or composition bearings, as these are melted in a fire; the attachment of large lubricators with well-fitting dust-proof covers; few brass or gun-metal minor accessories of a removable description, such as lubricators or oil-cup caps, etc., as these are ally stolen, and considerable inconvenience results. The before-mentioned ef-valves to the cylinder drain-cocks are essential, and the same should be ched to the steam-chest also. Special facilities should exist for easily and idly packing the glands and tightening up the bearing-brasses, and provision reversing the direction of the engine should not be overlooked, as some

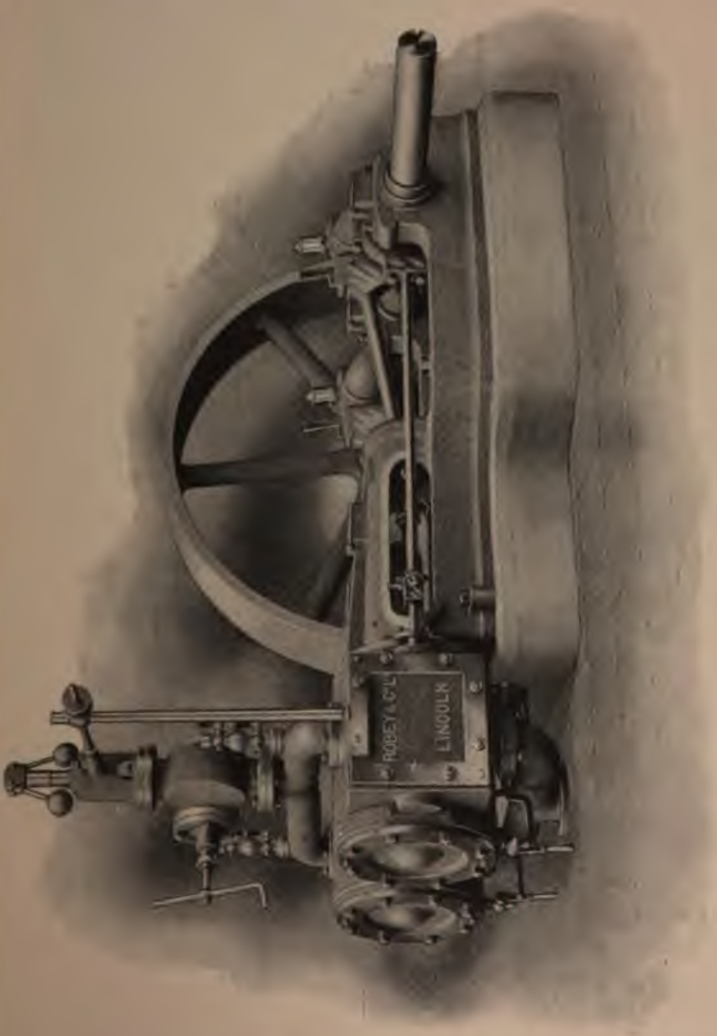

Fig. 57a.—Robey's Steam-engine as used for Bailing Russian Oil Wells.
(Sizes 12 inches × 16 inches and 14¼ inches × 18 inches.)

kes have no arrangement by which this can be done easily, and the position he eccentric has to be changed on the shaft, or the crank-shaft reversed.

The usual size of pulley used for bailing is 4 feet diameter and 14 inches e, and the fly-wheel is from 6 feet to 6 feet 6 inches diameter, and weighs ut 60 poods, the bulk of the weight being concentrated in the rim.

Oil-engines.—During the last few years several types of oil-engines have been introduced and used for the boring and bailing of wells, as they are, in many respects, peculiarly adapted to the exploitation of properties situated a long way from pipe-lines, from which fuel and water can be obtained, and where the expense of the erection of boiler-houses and permanent plant is inexpedient until the quality of the ground is tested. Oil-engines can also be turned to good account on plots of limited area, where the presence of a boiler-house with all its legal restrictions as to distance from derricks and boundaries, causes a large proportion of the land to be thrown out of profitable exploitation. Moreover, by means of oil motors, pieces of land which would have to be abandoned by the owner, or sold to neighbours, owing to insufficient space for a boiler-house, or where the cost of any other available power would be too excessive to allow a profit, can be economically worked.

Oil-engines working both by benzine and crude oil are to be found on the oil fields, the former chiefly of German manufacture, the latter, with one or two exceptions, of English make, and it is scarcely surprising that at the wells the latter type should have gradually superseded the benzine class. Several engines working direct with crude oil, without the assistance of an intermediary gas-generator, have been tried with indifferent success; but Messrs. Hornsby, of Grantham, is the only firm which has given careful consideration to the subject of manufacturing an engine which fulfils the oil-well conditions.

The majority of oil-engines consuming crude oil rely upon lamps for heating up the vaporizer prior to starting, which in itself presents an element of danger where gaseous wells exist; but during work the vaporizer and the exhaust-pipes reach a temperature which is quite capable, under some conditions, of exploding petroleum gas or firing a crude oil spray. The benzine motors are generally fired electrically, both at starting and in working, thus avoiding all danger; but it is doubtful whether the storage of benzine on an oil property does not form a danger equal to or even greater than lamps. The modern Hornsby engines are started electrically by the ignition of gas evolved from benzine admitted for a short time on starting by a three-way cock. The electric spark from a small magneto-electric machine, operated by a cam, explodes the benzine vapour when mixed with the requisite proportion of air, and compressed to the proper degree, an impetus being thus imparted to the piston. The engine is run with benzine until the vaporizer reaches a temperature high enough to ignite the crude-oil spray. Both the vaporizer and the exhaust-pipe and valve chambers are encased in a water-jacket, which protects all the usually exposed parts that might exceed a harmless temperature.

The utility of oil-engines for general boring and bailing has not yet been fully demonstrated, but for isolated wells their value has been again and again proved, and their employment steadily increases. Steam is a power very difficult to excel for most purposes, as it is generated in an easy manner, and the engines not only form one of the simplest motors for developing energy known, but are free from all complicated parts, and have a larger range of power than any other motor. The mechanical construction of a steam-engine is such that few connections are liable to get out of repair without due notice; the engine can be placed in charge of any ordinary employee of average intelligence, and it will work when in such a condition that any other class of motor would be set aside for overhauling. Oil-engines, on the other hand, which are of a much more intricate construction, and run at a high speed, require much greater care and skill in manipulation, and must be at once stopped and put into order when some little defect develops. Their power, too, is closely restricted to the specified strength, and they are more adapted to running with a continuous load than with a constantly fluctuating one, as in bailing or boring. For large powers, the sizes of oil engines reach clumsy proportions, as they are provided with only one cylinder, are single-acting, and the pistons receive an impetus only once every two revolutions. Oil-engines require a large reserve of good water for cooling purposes, especially in the hot summers experienced in the Caucasus, and the foundations have to be exceedingly well made to resist the vibration resulting from the periodical impulses and high speed.

The cost of an oil-engine in the Caucasus approximates to the value of a steam-engine and boiler with the usual accessories, but an enormous saving is found in the consumption of fuel, which averages only ¾ lb. of crude oil per brake horse-power per hour compared with 5¼lbs. to 7 lbs. for steam. Thus an ordinary 14-inch × 18-inch double-cylinder steam-engine developing 80 horse-power, under load 50 per cent. of the time, consumes 210 lbs. per hour, or 140 poods a day, under good local conditions, whereas an 80 horse-power oil-engine will perform the same work with a consumption of rather less than 60 lbs. per hour, or 40 poods a day, the efficiency of the oil-engines thus being 3·5 to 4 times that of steam. The fuel consumption of oil-engines would be even less, but for the fact that they do not work economically when not running under full load or when running quite idle.

The diagrams (Fig. 58) are taken from a 25 and a 50 so-called brake horse-power Hornsby engine—running with crude oil taken from the wells they were bailing—which indicate 32·9 and 66·2 horse-power respectively, and if the mechanical efficiency of the engines be taken as low as 80 per cent., the actual horse-powers available for work are 26·3 and 52·9.

Although the use of oil-engines reduces the consumption of fuel to about one-fourth that needed for steam, there are other points to consider before arriving at a decision to largely adopt them. The responsibility of keeping a number of large oil-engines in working order under the common oil-well conditions is considerable, for unless there is a skilled attendant at each engine, a slight defect may in a few moments develop into a serious accident. In one case recently, the pin attached to the governor-link of a 50 horse-power oil-engine fell out, and the engine, no longer under control, ran away at a frightful speed, but apparently, when a certain velocity had been reached, perhaps, 500 or 600 revolutions a minute, the effect of the explosions was to apply a brake, and by preventing a further increase of speed, saved the engine from total destruction. The alarmed attendant, losing all presence of mind, instead of holding the governor-link in his hand, shutting off the inlet valve or pressing down the pump-lever out of action with the cam, ran to call a fitter, who arrived about 5 minutes afterwards, in time to save the engine from serious harm, but not soon enough to save the engine-house from being partly wrecked, and the concrete foundation sinking more than a foot into the ground.

In another example, the lower bolt of the brasses of the crank-shaft end of the connecting rod broke, causing a complete wreck of the 50 horse-power engine; even the water-jacket of the end of the cylinder being fractured by the impact of the forcibly impelled piston after release from the crank-shaft.

An accident to an oil-engine, it will be seen, is not such a trivial matter as with a simple slow-speed steam-engine; and the great cost and more delicate work about the former are always a source of anxiety when attendants of doubtful ability are in charge. An oil-engine cannot be removed and replaced by another in a few hours, as is the case with a steam-engine, nor can a defect, as a rule, be remedied in the same short time, and this constitutes a serious objection to engines of large power fixed at very productive wells.

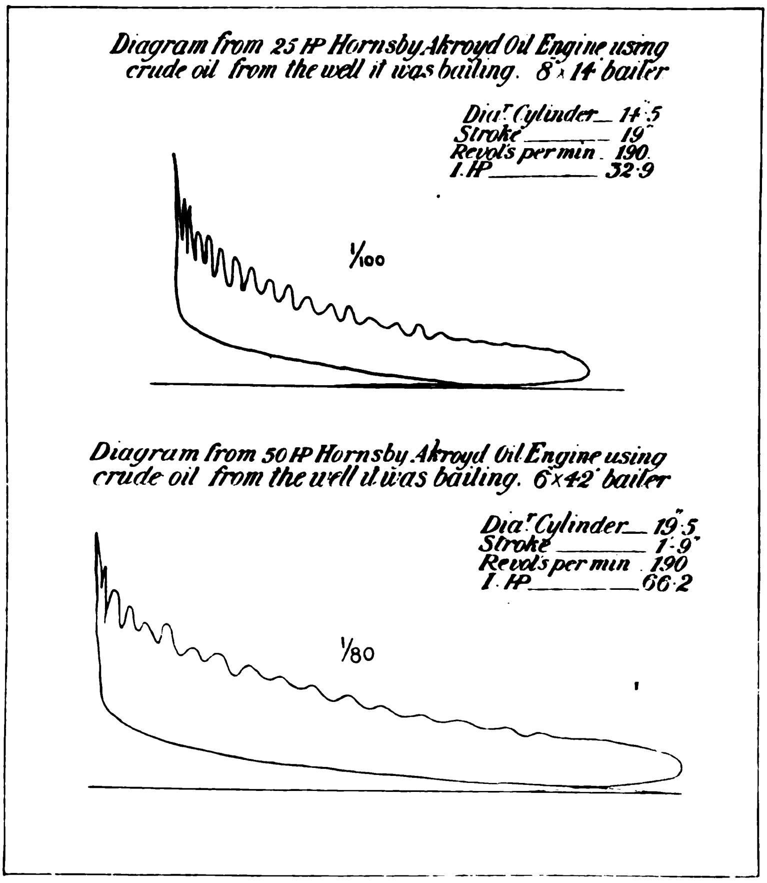

Fig. 58.—Diagrams from Hornsby-Akroyd Oil Engine when bailing Oil Well and using Crude Oil.

(Engines not purposely cleaned or oiled for the tests.)

Oil-engines do not admit of combination like other motors, and where attempts have been made to couple up a number of engines to one shaft, failure has resulted.

The erection of such valuable engines makes it imperative to construct fire-proof buildings for their reception, built of iron, asbestos-covered woodwork, masonry, or other non-inflammable materials; iron buildings, however, are the best and safest, and offer the least difficulties in removal.

Oil-engines are peculiarly adapted for driving pumps and air-compressors in stations and workshops, as they are then constantly under the eyes of an artisan, and are lodged in a well-made dust-proof building; but it is very doubtful whether they will ever be brought into general use for bailing purposes. On some properties, such as those in Grosny and certain districts in the Baku fields, where the wells are nearly dry, and only small power is required, oil-engines might very economically be employed by arranging for one motor of large power to drive a main shaft to supply power to a number of suitably placed wells.

Users of oil-engines should always keep a stock of spare parts, comprising vaporizers, piston-rings, oil-sprays and accessories, pump connections, skew gearing for countershaft, and bevel-wheels for governor, springs for all parts, electric ignition apparatus or lamps, and lubricators.

Care should be taken to clean the engine thoroughly every ten days, as in that time, if the engine is run continually, a small collection of coke forms on the inside of the vaporizer opposite the spray, and the valves get dirty. The water circulation tubes and the water-jackets surrounding the hot parts should also be examined, as where calcareous or saliferous waters are used, the tubes, after a time, become clogged with a deposition of lime or salt, which impedes the free circulation of the water and thus seriously affects the cooling of the parts. Water taken from wells in the Zabrat district—generally sold for drinking purposes in the Balakhany-Saboontchy area—causes a very heavy deposit, and sometimes the circulation tubes, after employment of this water, have been found with only $\frac{1}{8}$-inch passage through the centre. Condensed or rain water should be collected and used, where possible, for cooling purposes, the daily loss through evaporation being made up by the addition of the same kind of water.

In order that the foundations of oil-engines might be cheaply made and easily removed from time to time, a trial was made with a foundation of timber, after the style of those used for steam-engines, and engineers need not hesitate to follow the practice, as the results have more than satisfied expectations.

The high speed of oil-engines prevents direct transmission of power between the engine and bailing drum, and provision must always be made to reduce the speed by a countershaft with properly speeded pulleys. Fast and loose pulleys should be arranged on the countershaft to receive the drive from the engine, as in starting every facility must be given for freedom of motion and absence of friction.

Large oil-engines are fitted with starting gear, and in the Hornsby engines the starting is effected by the impetus given to the piston by admission of compressed air collected in a receiver and regulated by a hand-lever attached to the side of the engine. When the engine is running, the air is automatically pumped into the receiver, but a small hand air-pump is always supplied, so that the air supply may be replenished without the aid of the engine, if the accumulator is exhausted.

The Hornsby-Akroyd oil-engine is the only engine working directly with crude oil which has been extensively in demand on the oil fields, although a few others, possessing a separate generator wherein gas is prepared and then admitted into the cylinder, have been introduced. The Hornsby-Akroyd engine is described as follows in a pamphlet issued by Messrs. Hornsby and Sons, Ltd. :—

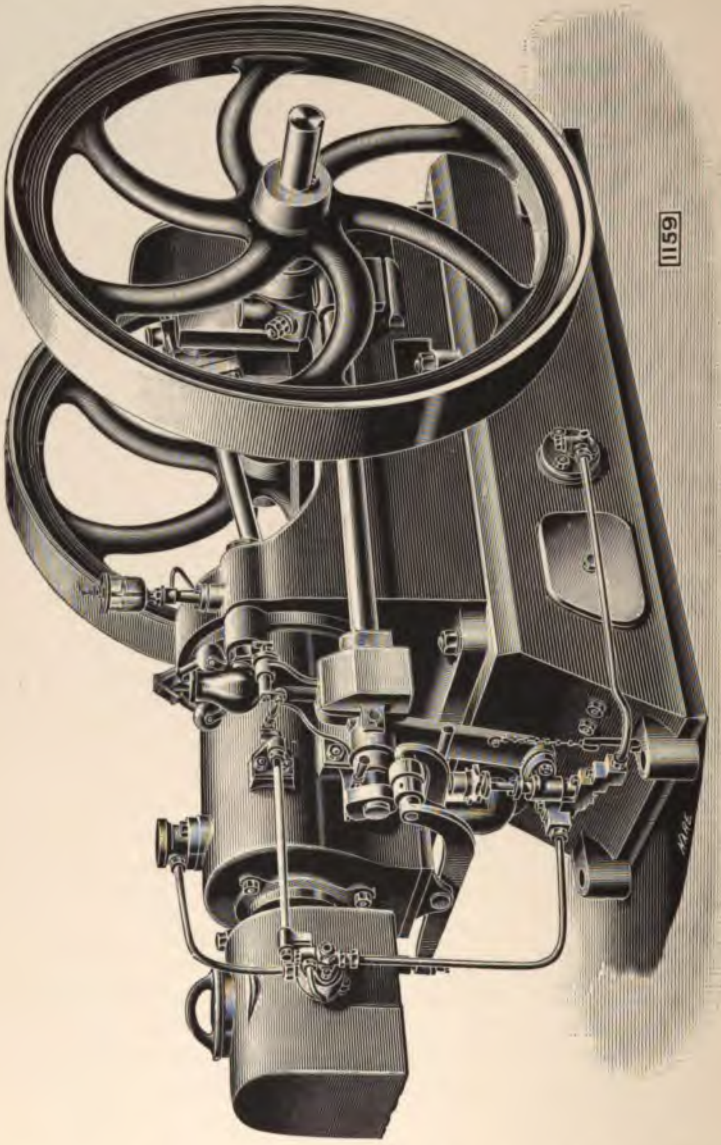

Fig. 59.—Hornsby-Akroyd Oil-engine.

"The engine is constructed with a working cylinder open at one end to receive

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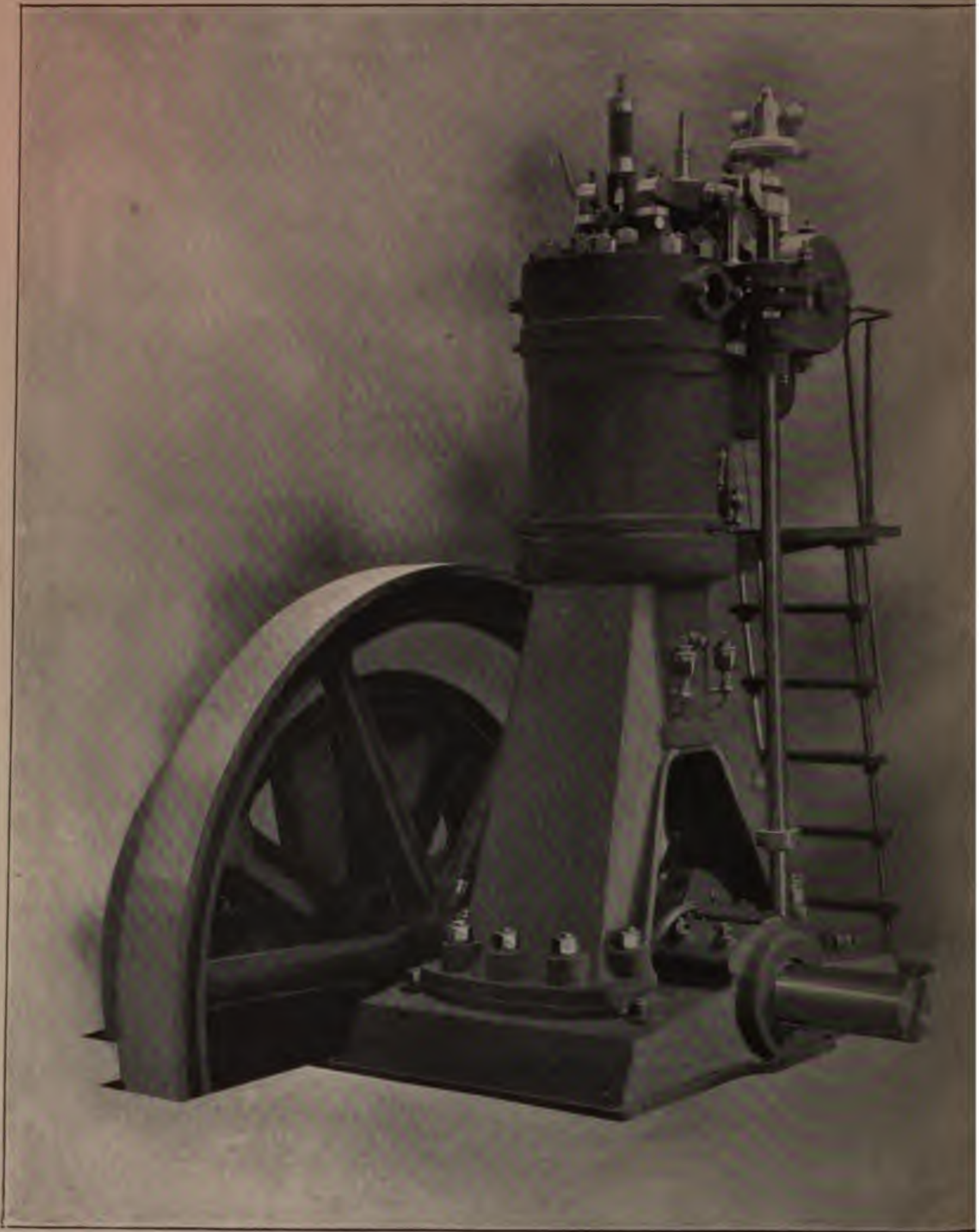


Fig. 60.—The Diesel Motor.

the piston, and closed at the other except for a neck connecting it with the vaporizer. The connecting rod is attached at one end to the inside of the piston, and at the other to the crank outside the cylinder; near to its closed end a valve-box is fixed, containing two valves, one being the air-valve, and the other the exhaust-valve. These valves are opened by separate levers, each lever being moved by a cam mounted on a horizontal shaft driven through skew-gearing by the crank-shaft.

"At the back of the cylinder is the vaporizer, which is a metal box open to the cylinder through the neck before named. To enable this vaporizer to vaporize and ignite the oil pumped into it, it is, at starting, heated by an external lamp; and when the engine has started, this lamp is no longer needed, the required heat being maintained by the internal explosions. (The lamp is unnecessary in the special engine made for the oil fields.)

"The oil tank is under the engine, and from it the oil is drawn by a small oil-pump, and during the outstroke of the piston, when, as afterwards explained, it is drawing in air, forced into the vaporizer.

"On its way the oil passes through a valve-box having two valves, one of which admits it to the vaporizer, the other being opened by the governor (whenever the engine is running too quickly), so as to allow some of the oil to flow back by the waste-pipe into the tank.

"The engine works on what is known as the 'Otto four-cycle' plan, the series of operations being completed by every two complete revolutions of the crank. This may be described as follows:—

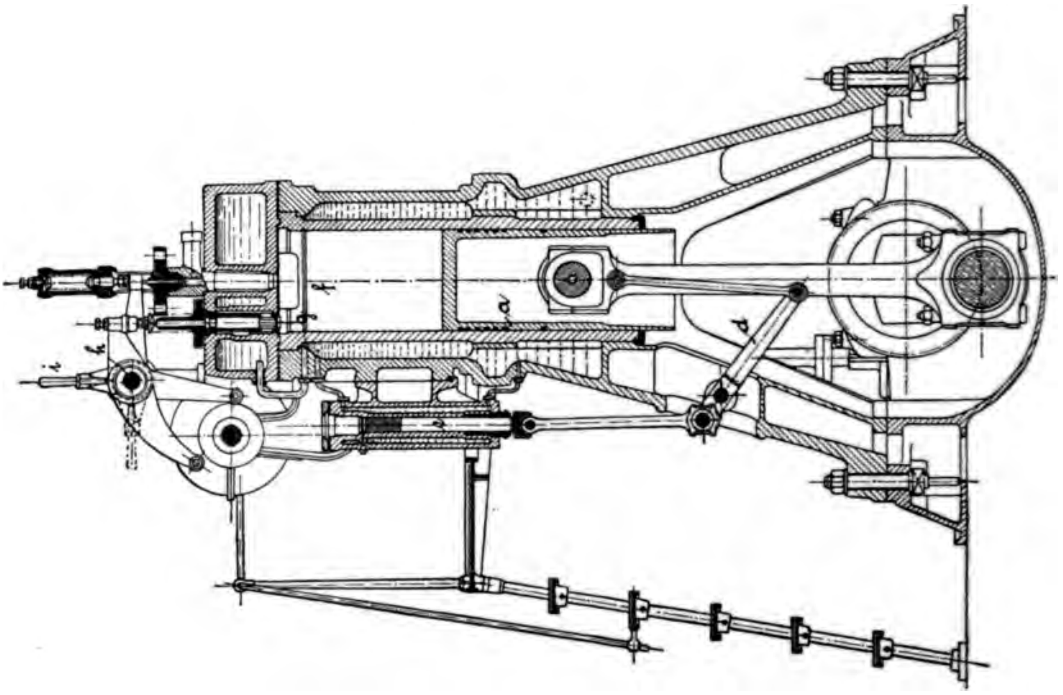
"Starting with the piston right home at the back end of the cylinder, on the fly-wheel being turned round the first outstroke of the piston will be made, drawing in air behind it through the suction-valve. During this time oil has been forced into the vaporizer, and this having been heated, as previously explained, oil vapour is therefore formed. When the piston reaches the end of this first outstroke, the air-valve closes, and the piston on its return stroke forces the air and oil vapour behind it into the remaining space at the end of the cylinder, and through the neck into the vaporizer, thus completing one revolution of the crank.

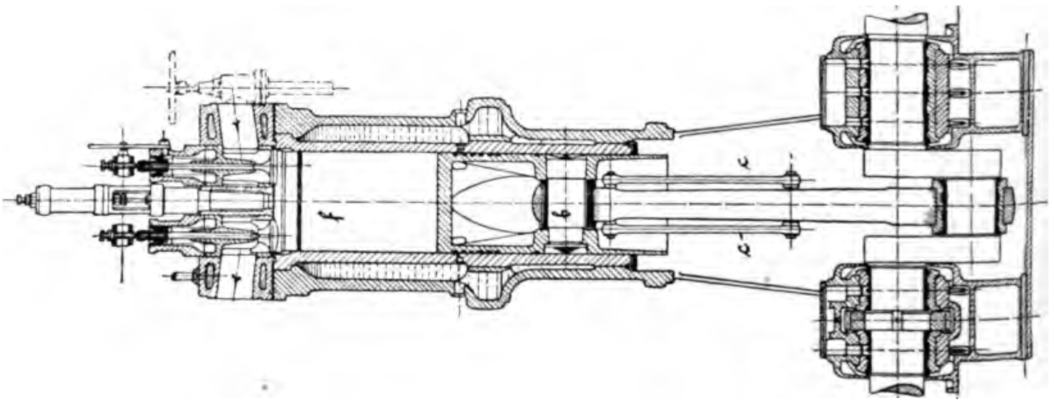
"At this point the heated vaporizer ignites the compressed mixture of oil vapour and air, and supplies the force for the second outstroke of the piston. At the end of this stroke the exhaust-valve opens, so that on the return stroke or second instroke the burnt gases are expelled through the exhaust. This completes the second revolution of the engine, and the same series of operations begins again; so that it will be seen that the power of the engine is obtained during one outstroke in every two revolutions."

The makers also recommend that sufficient cooling water should be supplied to prevent the water from leaving the cylinder at a higher temperature than 120° Fahr., and not lower than 100° Fahr.

Diesel Motor.—Most oil-engines in the market to-day (1902) will not work satisfactorily with crude oil, but the "Diesel" motor has recently been brought to a high state of perfection, and its excellent qualities and peculiarities are likely to bring it largely to the front during the next few years.

In *The Engineer* of May 30 and June 13, 1902, is an article which speaks very flatteringly of the working of this engine, and quite reversing that journal's opinion, which had previously been unfavourable. The special features of the engine which distinguish it from all other oil-engines are, according to *The Engineer:* "(1) The attainment of a temperature necessary for





ignition by mechanical compression alone, so that all injected flame, incandescent tube, electric spark, or other extraneous igniting device, is abolished. (2) The injection of the fuel only after compression has been completed, and only during the first part of the working stroke, the compression in the working cylinder being that of air alone. Thus no explosive mixture exists in the cylinder before the beginning of the working stroke, and no premature ignition is ever possible. (3) The fuel is injected gradually into the highly heated air, each drop of the spray burning immediately and quietly, so that no explosion takes place, while the period of injection and quantity injected are delicately regulated by the governor in accordance with the demand for power. (4) Thus the governance is effected within the four-stroke cyclic period of thermo-dynamic action, and every such period has its working stroke."

It is claimed that this engine will consume almost any class of fuel, and although it is very expensive and somewhat complicated, its use will, no doubt, quickly extend. The author has been informed that the wear of the valves is so great that it is necessary to retain the services of a skilled mechanic to grind them down to their seatings, and if this is so, it constitutes a serious objection to the engines in outlying districts.

Some tests made in 1899 with Russian oil of a specific gravity of 0·870 to 0·880, having a calorific value of 19,650 British Thermal Units, gave a fuel consumption of about half a pound per brake horse-power per hour, and the manufacturers are prepared to guarantee the consumption according to the following scale:—

Brake horse-power	4	10	20	50	70
Oil consumption in pounds per brake horse-power per hour . . .	0·60	0·51	0·48	0·44	0·42

The cost of the Diesel motor greatly exceeds that of a steam-engine, boiler, and accessories of the same power.

Gas-engines.—Gas-engines have not been employed directly for bailing purposes, as no use is made of the natural gas evolved from the wells, but indirectly they have been for several years used for generating electric power, which in turn drives the wells. Details of the plants used for the manufacture of petroleum gas from crude oil and the cost of gas power are given in Chapter XIII.

Power needed for Bailing Wells.—In changing from steam- to oil-engines and electric power, many mistakes were made at first in erecting motors of insufficient strength, which had eventually to be replaced by those of greater power, the actual horse-power developed by a 25 or 35 nominal horse-power engine not being fully appreciated. The appended table shows the actual maximum powers needed to bail wells 1400 feet deep with different sizes of bailers; the weight of bailer and 1400 feet of wire rope is added ($\frac{5}{8}$-inch diameter rope up to 10-inch bailers, and $\frac{3}{4}$-inch for bailers from 11 inches to 14 inches inclusive), but no addition is made for friction, as this is nearly always balanced, or more than compensated for, by the reduced weight of the bailers' contents through lightening by gas. In very gassy wells, where the liquid is much lightened by gas, 10 to 20 per cent. may be deducted from the horse-powers given. The size of the bailer should be at least 3 inches less in diameter than the internal dimensions of the well casing, where there is much liquid present, or the friction of the ascending bailer becomes very great, and the power required to draw the bailer through the fluid exceeds that named in the table.

TABLE XXII.

GIVING THE ACTUAL HORSE-POWERS REQUIRED TO BAIL AN OIL WELL 1400 FEET DEEP, WITH DIFFERENT SIZES AND LENGTHS OF BAILERS, AT VARIOUS SPEEDS. ALSO SHOWING CAPACITIES OF BAILERS IN POODS.

Length of bailer in feet.	7 inches.					8 inches.					9 inches.					10 inches.					Length of bailer in feet.
	Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		
	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	
	800	900	1000			800	900	1000			800	900	1000			800	900	1000			
1				0·40	0·47				0·52	0·61				0·66	0·77				0·82	0·95	1
10	10·3	11·5	12·5	4·01	4·68	12·3	14·0	15·5	5·24	6·11	13·5	15·5	17·0	6·63	7·73	15·5	17·5	19·5	8·18	9·54	10
20	20·5	23·0	25·0	8·02	9·36	24·5	28·0	31·0	10·48	12·22	27·3	31·0	34·3	13·26	15·46	31·3	35·0	39·0	16·36	19·08	20
30	30·7	34·5	37·5	12·03	14·04	36·7	42·0	46·5	15·72	18·33	40·5	46·5	51·0	19·89	23·19	46·5	52·5	58·5	24·54	28·62	30
40	41·0	46·0	50·0	16·04	18·72	49·0	56·0	62·2	20·96	24·44	54·7	62·3	68·5	26·52	30·92	62·5	70·3	78·0	32·72	38·16	40

Length of bailer in feet.	11 inches.					12 inches.					13 inches.					14 inches.					Length of bailer in feet.
	Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		Horse-power.			Capacity in poods.		
	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	Speed in feet per min.			Oil.	Water.	
	700	800	900			700	800	900			600	700	800			600	700	800			
1				0·98	1·14				1·18	1·37				1·38	1·61				1·60	1·86	1
10	16·3	18·7	21·0	9·89	11·45	18·0	20·5	23·0	11·80	13·70	17·0	19·7	27·5	13·80	16·10	18·0	21·0	24·0	16·00	18·60	10
20	32·7	37·5	42·0	19·78	22·90	36·0	41·0	46·3	23·60	27·40	34·0	39·5	45·0	27·60	32·20	36·0	42·0	48·0	32·00	37·20	20
30	49·0	56·3	63·0	29·67	34·30	54·0	61·5	69·0	35·40	41·10	51·0	58·3	82·5	41·40	48·30	54·0	63·0	72·0	48·00	55·80	30
40	65·5	75·0	84·0	39·56	45·80	72·0	82·0	92·7	47·20	54·80	68·0	79·0	90·0	55·20	64·40	72·0	84·0	96·3	64·00	74·40	40

The action of bailing gassy wells from the bottom, when there is much liquid present, is peculiar, for the gas-supersaturated fluid admitted into the bailer at the bottom of the well, where the pressure due to superincumbent liquid may amount to several hundred pounds per square inch, is retained in that state during its enforced ascent through the oil, but immediately the bailer emerges from the oil and the resistance is removed, a violent evolution of the dissolved gas ensues, and 30 to 80 per cent. of the total contents of the bailer may be vigorously ejected into the well, causing the steam-engine to "race," often to a dangerous degree, unless governed.* The force with which the contents of the bailer are expelled is so violent in some cases that it amounts almost to an explosion, and the noise created by the action is distinctly audible at a distance; indeed, in most gaseous wells the noise accompanying this ejection may be heard if the mouth of the bore-hole is closely approached. This action is clearly exhibited in the indicator diagrams I. and II. (Fig. 62), which are taken from a steam-engine, governed to run at a regular speed, bailing a moderately

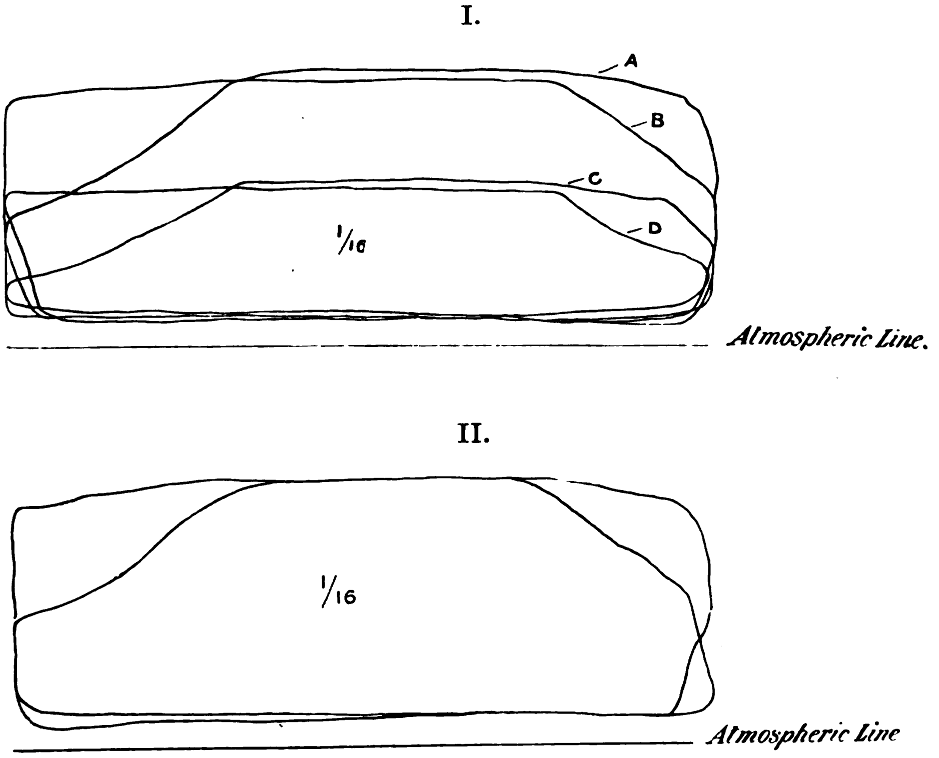


Fig. 62.—Diagrams taken from a 14-inch by 18-inch Double-cylinder Steam-engine when bailing a Baku Oil Well.

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* The author has had under his notice many examples of wells where for weeks bailers taken from the bottom did not contain 10 per cent. of their capacity, and has even seen bailers raised empty through this cause alone.

gassy well 16 inches diameter, 1300 feet deep, with 700 feet of liquid, by a bailer 10 inches diameter and 42 feet long. The diagrams were taken by the author very rapidly in the order named: A and B as the bailer was being drawn through the liquid at a velocity of 880 feet per minute, and C and D after the bailer's emergence from the fluid, and during its ascent, at the same speed, in the open bore-hole. That the difference between the diagrams A and B was not due to friction in the fluid is illustrated by diagram II., which was taken immediately after diagram I., as the bailer was being raised in the open bore-hole after filling from the top of the liquid, which, it will be observed, closely corresponds with diagram AB, taken during the passage of the bailer through the liquid. The steam-engine was a 14-inch by 18-inch double-cylinder one, running at 75 revolutions per minute, and the diagram AB works out at 50·5 horse-power, when the actual theoretical horse-power required to lift that size of bailer *full of oil* at the governed speed is 65 horse-power, without taking into account any friction, or fully 80 horse-power inclusive of friction. As the friction of a 10-inch bailer in a 16-inch well at the speed run is quite insignificant, the difference between the diagrams AB, and CD gives a means of calculating the amount of liquid ejected from the bailer on its emergence from the oil, which in this case is approximately 50 per cent. In non-gaseous wells the reverse action to that described is always observed, the reduced weight of bailer and contents through suspension in the liquid actually causing the engine to run faster when the bailer is in the fluid than out, the point of emergence from the liquid being rendered apparent by the reduction of speed of the engine if not governed to run at a regular rate.

Electric Power.—Years ago two or three Baku firms made attempts to utilize electric power on the oil properties, for which work it is peculiarly adapted, removing, as it does, the necessity of boiler-houses and so fires in the vicinity of oil wells, and although at that time the generation of electric power had not reached the perfected state it has to-day, the trials, at least demonstrated the utility of such energy. Messrs. Benkendorf designed a large generating station in Balakhany, in which a number of oil-engines produced the necessary power by driving on to a main shaft, which in turn transmitted the drive to the generators—a system which, from the very outset, proved unsatisfactory, for oil-engines, which rely largely upon the momentum stored in fly-wheels for their working, do not admit of coupling up with success. In Nobels' Saboontchy station the generators are driven by means of large gas-engines, which derive their gas from a gas-producing plant working in conjunction with the installation, and from which a valuable gas of a high calorific power is generated from crude oil supplied to retorts arranged on the Pintsch principle. The same system is adopted by the Caspian and Black Sea Company in their Zabrat station for generating electric energy; the only important difference lying in the method of manufacturing the gas, which, it is said, has failed to satisfy requirements, and the producer plant is undergoing complete alterations. The Baku Electric Power Co.'s stations are luxuriously fitted up in the most modern manner, and in the Baieloff station there are four 500 horse-power triple-expansion high-pressure condensing engines coupled directly to generators, the steam being raised in water-tube boilers fired by liquid fuel, and fed by water obtained from a condensing plant erected in connection with the installation. The above company's extensive works erected at Baieloff for the supply of energy to Bibi-Eibat, and at Blacktown for the supply of power to Balakhany and Saboontchy, were only completed in 1901, and had the crisis in the oil business not been contemporaneous with their erection, the use of the power would have greatly extended. The Public Electric Power Company conducts the electricity to the oil fields by overhead mains, and distributes the energy about the oil properties by underground cables following the principal roads, but private concerns keep to the overhead method, notwithstanding its danger, and rely upon the protection afforded by a wire cradle supported beneath the lines, which prevents them falling to the earth in the event of a breakage occurring through high winds, snow, or fire. Fire-proof transforming stations are erected in central positions, from which the live wires are led to the various motors at the wells, and each service line is intercepted by a wattmeter that records the actual power that is being supplied to that motor, so that a single attendant may sit in an office and note exactly what is being done at each well receiving power through his box. The author is indebted to Messrs. Nobel for the accompanying diagrams (Fig. 63) plotted from data supplied by such a recorder, from which it will be observed that a perfect record of the bailing can be preserved, and the position of a bailer in a well at any moment known, the time and duration of any stoppage registered, and the diligence with which a bailing man attends to his work, accurately ascertained.

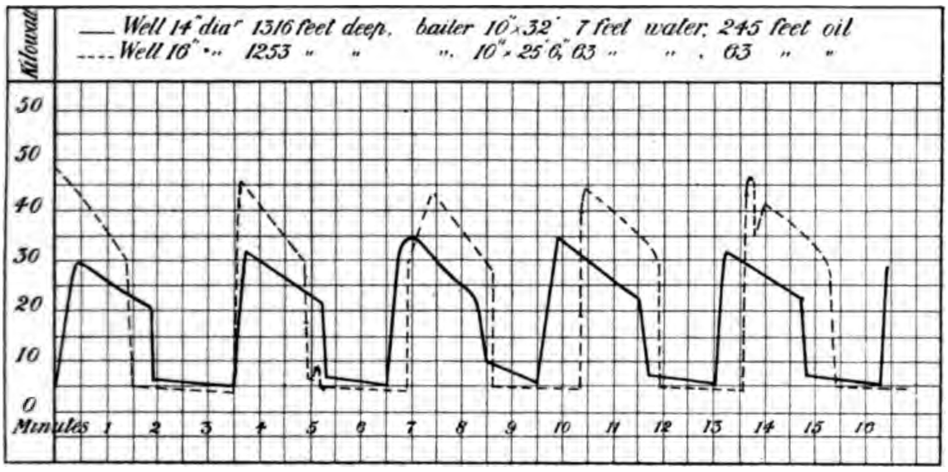

Fig. 63.—Diagrams plotted from Data furnished by Recording Kilowattmeter which intercepted the Current supplying Motors for bailing Oil Wells.

The electric motors erected near the derricks are usually protected by a small brick-work, fire-proof, and as nearly as possible dust-proof, structure, only just large enough to contain the motor and permit the movements of an attendant; and the exit through which the driving belt passes is preserved by a sheet-iron sliding door that can be closed, or falls automatically whenever a fire attacks the derrick and threatens the destruction of the motor. The speed of the electric motors, which usually approximates to 700 revolutions per minute, is reduced down to workable proportions by the interposition of a countershaft fitted with pulleys of suitable dimensions, which transmit the power, through the medium of a belt, to the bailing drum or machinery in the derrick.

Many objections, described as insuperable obstacles by adverse critics of the innovation, were raised in the early stages of electric power, such as impossibility to regulate the speed of the motor, sparking, etc., etc.; but all difficulties have been surmounted except, perhaps, the most serious of all, namely, that of cost. The Baku Electric Power Co., in their general circular, advertise the power at the following rate:—

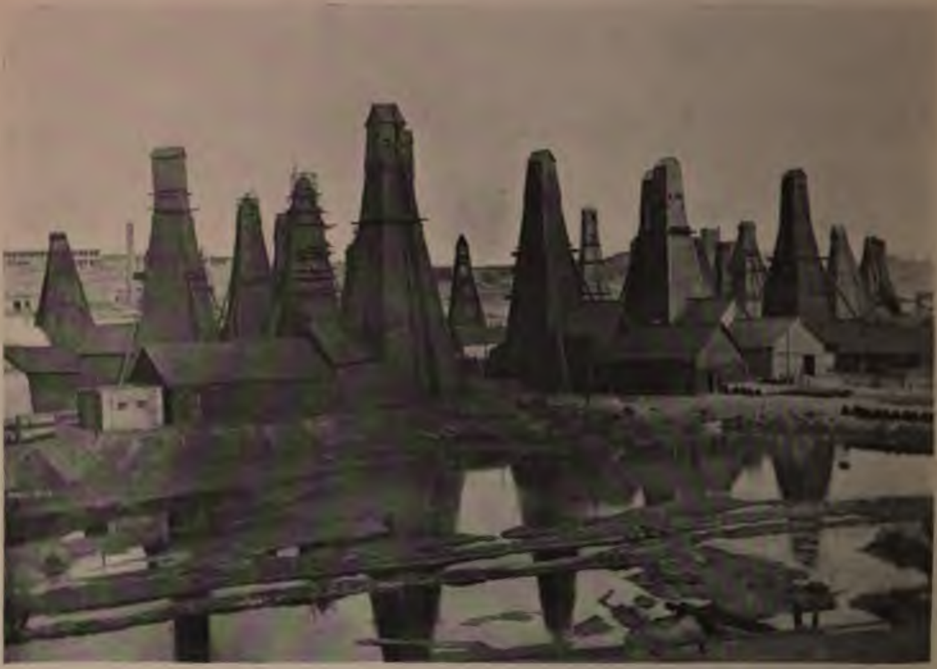

Fig. 64.—View of Romany Oil District, showing Romany Village and Castle in Background, and Well bailed by Electric Power in Foreground.

(Motor protected by small brick building.)

(*a*) For boring wells . . .	425 roubles per month
(*b*) For bailing wells . . .	450 „ „ „
(*c*) For pumps, etc. . . .	6 copecks per kilowatt-hour

These prices are not exceeded so long as the official price of crude oil does not rise beyond 8 copecks per pood, but for each copeck rise above this figure the company has the right of increasing the price of the power by 20 roubles per month, or 0·2 copeck per kilowatt-hour. The company also states that a 10 per cent. reduction is allowed when power is taken for ten or more wells, but during the recent trade depression and low price of crude oil the company has accepted prices 20 per cent. lower than the advertised tariff.

CHAPTER IX.

"AIR-LIFT" SYSTEM OF RAISING OIL.

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Consumption of Air.—Great variation under apparently similar circumstances, and therefore guiding data wanting—Possible consumption of an indefinite amount of air, and therefore careful adjustment necessary—Provision of air necessary to give reserve of power—Figures relating to installations at various wells.

Cost of Air Lift.—Primary expenditure and consumption of fuel as compared with bailing—Increased production more than counterbalances increased expenditure.

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Low-lift Systems.—Divisible into two classes—Valves essential in both classes, and consequent unsuitability in Baku district—Greater probability of success at Grosny, but not the same advantages derivable as at Baku—Description of Stirling's patent, the only system yet tested at Baku.

Compressors.—Requirements sought in compressor—Source of air supply—Provision for elimination of water—Precautions to be observed in working compressors—Inspection of air mains.

CHAPTER IX.

"*AIR-LIFT*" *SYSTEM OF RAISING OIL.*

Air-lift System of raising Oil.—Records exist in the Baku oil fields of some half-hearted attempts to introduce compressed air for raising oil many years ago, but although the value of air as a water lifter had been so abundantly demonstrated, especially in America, it is strange that few practical results should have been attained in its application to oil. In 1899, the first successful experiments in the Russian oil fields made with compressed air were obtained by the author for the European Petroleum Co., Ltd., which excited much local interest, and from which has started a new development on a large scale. In 1900, the Minister of Domains and Agriculture, with a large party of influential persons connected with oil, witnessed the working of two wells of the European Petroleum Co. by compressed air, and evinced considerable interest in the new system of raising oil.

Since 1899, experiments have been steadily conducted, and improvements introduced, until the air lift can be said to have been brought to a condition in which it will compete favourably with other methods under some circumstances, and which will commend itself for special cases where no other system could be successfully employed.

The air-lift process of raising oil is simply a modification of the Pohlé water lift, an invention which has been operated, perfected, and extensively worked in America, but which has only recently been applied in England. The liquid is raised by the direct aëration of a column of fluid in a confined space, thus becoming so lightened by admixture with the requisite amount of air that it is discharged from the surface. It is needless to wade through all the experimental details, and beyond an outline of the various arrangements tried, this will be avoided. In the first trials the air was conveyed down the well in a central 1-inch or 1¼-inch pipe to the estimated depth, and the liquid rose in the space between this tube and an outer one of larger diameter. The results were far from unsatisfactory, but the disadvantage of the system lay in the increased friction in the tubing, through contact with two surfaces—a resistance which is from 20 to 50 per cent. greater with viscous crude oil than with water, and which varies with the specific gravity of the petroleum or mixture lifted. At the base of the air tubes was attached a brass nozzle with an annular orifice, so constructed that it diverted the passage of the air vertically; but later experiments showed that the presence of this nozzle made little difference to nd it was found more advantageous to replace it by a plain bell-. If the supply of air were shut off for only a few moments when nt, the air nozzle usually became clogged, for the tubes invariably and as the air escaped, the liquid and sand rushed in to fill the ously occupied by the air. Before the apparatus could be restarted nd had settled compactly upon the nozzle, and choked the air outlet, t necessary to raise and clean it.

Later experiments were conducted by passing the air down between the two tubes and allowing the liquid to rise in the centre one, a suitable gland and stuffing box, with side fitting for the admission of the air, being provided. This latter method is the one generally adopted for the raising of oil, but there are several modifications in the manner of admitting the air. The various arrangements are shown in Figs. 65 and 66. Before dealing further with the subject, advantages claimed by the users of compressed air will be enumerated, an idea will thus be obtained of the objects the promoters of compressed air have in view. The unique characteristics of the air-lift system are—

(1) Its automatic action and reliability.

(2) The possibility of bailing wells of small diameter as well as crooked bore-holes.

(3) Reduced working expenses.

(4) No agitation of liquid and no wear of casing.

(5) The removal of liquid only from the bottom, and consequently the impossibility of *water* or *plug* collecting.

(6) No derrick required, and consequently no danger from fire.

(7) Small space occupied on valuable land, and the advantage of being able to erect all the plant on surface-rights land.

(8) Ease of transmitting compressed air *without great loss* as occurs with steam.

(9) Concentration of all machinery in one building.

(10) Absence of all wearing parts and fittings liable to get out of order.

All these peculiar qualities possessed by compressed air are recognized as almost ideal in nature, but unfortunately the use of compressed air in the Baku oil fields is so far confined to one class of well, a type of greater rarity as each year passes. Americans determined years ago that compressed air could be economically employed for raising water when there was a submergence of at least 60 per cent., and experiments have proved that when dealing with oil almost similar conditions are essential, and that but poor results can be realized if the proportion of submergence to lift does not reach 50 per cent.

Dr. Pohlé, it is said, obtained the best results by having a submergence equal to twice the lift, but his experiments, like most of those from which any information is procurable, were made in shallow wells, whilst those of the oil regions are rarely less than 1000 feet deep, and may exceed 1700 feet. With water there are some quantities which constantly recur, and still no reliable rules have yet been formulated from which the amount of liquid and consumption of air for various submergences can be ascertained; but with petroleum the subject is rendered tenfold more difficult by reason of the widely divergent features which present themselves in each well operated.

Let the value of each of the qualities claimed for compressed air be now more closely considered.

(1) *Its Automatic Action and Reliability* are features which commend the system in preference to all others; for there is none of the constant stoppages which occur in bailing wells, such as oiling engine, packing glands, etc., repairing belts and ropes, changing bailers, accidents to and loss of bailers in wells, constant attention to bailing drum, etc., etc., the time upon which steadily accumulates, and in a week reaches quite a considerable figure. No attendant is needed upon whose vigilance night-work depends, and if, as would be the case where compressed air was extensively used, spare compressors are fixed, there need be no stoppage for any purpose after once getting a well to work. The importance of a steady removal of liquid without intermission will be appreciated by all practical men who know to how great an extent a well may suffer by even a short stoppage in the bailing.

(2) *The Possibility of raising Oil from Wells of Small Diameter, and from Crooked Bore-holes.*—The difficulties which attend the bailing of wells of small diameter, and crooked holes, are described in Chapter VIII., and it will be readily understood to what an extent compressed air can be applied to this type of boring.

A production from a 6-inch well may, under suitable circumstances, be as much as from a well of 20 inches diameter, without being placed under the same risk, and a boring of such dimensions, as by bailing with a miniature bailer will yield only water, may give from 5000 to 10,000 poods of oil daily when fitted with air lift.

(3) *Reduced Working Expenses.*—Although the initial expenditure for a compressed-air installation is great, the working expenses are considerably less than by bailing. The arrangement of a number of compressors in a single station, under the immediate supervision of a skilled mechanic, and protected from the unfavourable climatic conditions by a substantial structure; the reduced wear and tear of belting; the absence of steel-wire ropes which cost large sums of money and wear but a few months; the entire absence of bailers and their expensive daily repairs;—lead to an economy which can only be fully realized by those intimately connected with the practical working of an oil property.

(4) *No Agitation of Liquid or Wear of Casing.*—The suction action set up by a large bailer when being raised through a column of liquid at a high velocity, produces an agitation of the fluid in the well which, to say the least, it is better to avoid. Its effect is to encourage the formation of a plug periodically, and to excite the gas to an abnormal degree, as well as to mix the water and oil in the casing; but with the air lift the liquid is withdrawn continuously and not by impulses, and consequently there is no agitation or irregular formation of plug. The wear of casing is very slight in straight wells, but if the tubes lie the least out of vertical, the casing is rapidly cut up by the wire rope, and bailing rendered impracticable.

(5) *The Removal of Liquid only from the Bottom, and consequently the Impossibility of Water or Plug collecting.*—The importance of keeping a well quite free from water and plug is fully explained in Chapter X., but the value

of doing so could scarcely have been entirely realized until compressed air so conclusively illustrated the fact. The effect of such conditions is really astonishing, for wells which have been handed over to the air lift have yielded, in some cases, from five to ten times as much oil as was obtained by bailing, *although the total quantity of liquid raised by compressed air was* 30–50 *per cent. less than by bailing.* Air cannot be held responsible for the formation of petroleum, nor is there any definite affinity between air and oil, so that its appearance in larger quantities can only be explained by the greater freedom with which it gained admission through reduction of plug, diminution of water, and absence of all agitation and excitement by bailers.

It must be observed that the air-lift system in its simple application differs from all bailing in the very important feature that no appreciable quantity of oil can be obtained until the water is reduced to the inlet of the air-lift pipes and the whole of the submergence is oil.

(6) *No Derrick required, and consequently no Danger from Fire.*—The oil-soaked wooden derricks, and their prolonged timber engine-sheds, surmounting all productive oil wells, represent one of the greatest risks an oil property runs, and anything done to minimize the danger of fire constitutes an insurance of inestimable pecuniary value to the firm undertaking it. The adoption of the air-lift principle removes all risk of fire, and its universal use would at once have the effect of reducing the number of those fierce conflagrations which recur with diabolic frequency, and deal out destruction and desolation on all sides. All that is required at a well operated by compressed air is a light, portable steam, or electric winch, and a set of iron or wooden shear-legs by means of which the tubes may be lowered, and if the gases from the well do by any chance take fire, the damage is confined to the well, and the spread of the fire is easily checked.

(7) *The Small Space occupied on Valuable Land.*—One of the chief objections to the present system of bailing is the amount of space occupied by the derricks and adjacent engine-sheds on valuable land, which lumber up the property with highly inflammable material and limit the number of wells which can be located on a single plot. With compressed air, the whole of the machinery may be transferred to a separate property for which only surface rights are held, and the air may be conveyed to and distributed on the properties by mains, thus discarding all the steam-engines and bailing drums, abolishing all sheds for their reception, and freeing valuable land for profitable exploitation.

(8) *Ease of transmitting Compressed Air without Great Loss.*—The distribution of steam on an oil property is never accomplished without considerable loss (*vide* Chapter XII.); indeed, it is not uncommon to find 50 per cent. of the boiler power lost in friction and condensation in long, badly designed, and ill-protected steam lines. Compressed air is exempt from loss by condensation, and it is peculiarly well adapted, in this respect, for distribution over large areas, but the most careful inspections are needed to ascertain that no leaks exist in the mains, as an escape of air is not so readily discernible as an escape of steam.

(9) *Concentration of all the Machinery in One Building.*—It is unnecessary to point out the numerous advantages under such an arrangement, but in the Apsheron Peninsula they are particularly emphasized, owing to the frequency

of violent sandstorms, against which an ordinary wooden shed is no protection, and to the laxity of the employees whose duty is solely to inspect, lubricate, and keep in order the engines and drums on the property.

(10) *Absence of all Wearing Parts and Fittings liable to get out of Order.*—Perhaps the greatest blessing conferred by compressed air is the absence of all fittings liable to get out of repair, or brass parts to be stolen, the only tempting article of a removable nature being a pressure gauge. Even this is not quite safe from the night prowler of the oil fields, and, in one case, it was the means of capturing a man redhanded. A new polished brass 500-lbs. pressure gauge no doubt attracted the man's attention, who, after satisfying himself that the pipe was cold, and no *steam* was passing, proceeded to unscrew it. When but two or three threads were left, the pressure of 350 lbs. per square inch, which was on the main, blew the gauge into the air with great force. The thief was so stupefied at the result that he had not the presence of mind to run away, and was caught, before he had recovered his senses, by the watchman, who had been attracted by the explosion. The tubes, if properly adjusted, require no alteration for years if the output continues, and instead of deteriorating from use, they are actually improved by the polishing they receive from the rapidly moving liquid and suspended sand.

Air-lift Tubes.—As the wells in which the air lift is likely to be used vary from 1000 feet to 1700 feet in depth, tubes should be specified which are capable of standing a working pressure of about 400 lbs. per square inch (say 25 atmospheres), but which should be able to resist for a time a maximum pressure of 500 lbs. per square inch (say 35 atmospheres) without bursting.

The whole weight of the column of tubes must naturally be borne by the upper lengths, to support which with safety they should be supplied with extra long sockets, and for rapidity in lowering they should be given a slightly coarser thread than standard size. The tubes should be made to butt when screwed up tightly, and both tube ends and socket mouths should be slightly chamfered to prevent burrs and bruises, which seriously hinder the process of lowering. Ordinary steam tubes are not suitable for such high pressures, and when they have been employed, they have been an endless source of trouble from leakages and fractures; but the 4-inch oil pipe-line tubes, which are stocked in Baku for long distance oil mains, will stand a pressure of 35 atmospheres without any danger, and are well adapted for compressed air. Russian tubes may now be purchased which will conform with the requirements; but they must be specially ordered, when extra long sockets may also be obtained without much additional expense.

Solid drawn tubes manufactured in Russia on the Mannesmann system may be obtained, which are light and will resist a very high pressure, but they are irregular in thickness, and thin down considerably towards the middle of the lengths, so that they cannot be cut and rescrewed if they do not meet the exact requirements. For service mains the Mannesmann tubes may be employed and answer their purpose well. Before lowering the tubes into the well, they should be examined carefully to ascertain whether there are any protruding burrs on the inside, and should, if possible, be tested by hydraulic or pneumatic power. The tubes, if free from defects, improve with use, and after a few months' work they are given a high polish on the inside, which materially reduces the friction.

In some wells that yield much water, an incrustation is deposited on the interior of the rising main, and sometimes on the exterior of the tubes also, but it is exceedingly brittle, and can be removed by the application of a number of hard raps with a hand-hammer. The incrustation is probably due to the liberation of some of the dissolved carbonic acid by the agitation of the air, and the liquid on loss of carbonic acid gas, no longer able to hold the carbonate of lime in solution, deposits it upon the tubes with which it comes in contact. This explanation is supported by the fact that it has been observed at some wells, that objects placed in the canal discharging water from an air lift have become petrified, or rather coated all over with calcareous matter. It was noticed that the thickest accumulation on the exterior of the tubes was situated near the average line of water-level, and that it was confined to a hundred feet or so in the vicinity of this level. This would be deposited, through the natural evolution of the carbonic acid, from the liquid in contact with the portion of the tubes which came under the influence of a fluctuating water-level, and became alternately submerged and dry. Such a deposit, if only small, serves effectually to protect the tubes from the action of corrosive or highly saline waters in the well without producing any ill effect.

Depth of Tubes in Well.—To obtain the best results with compressed air, the bottom tube, which also forms the suction,* should always be placed level with, or about 1 foot below, the shoe of the lining tubes of the borehole, so that it is advisable to clean out the well and make an accurate measurement before commencing operations. By this means the well is always kept quite clear of plug, and a perfectly free inlet for the oil is left; but some engineers prefer to sink the suction tube 7 to 10 feet below the casing shoe, claiming that a better result is so obtained. When the suction tube is placed a long distance below the shoe, there is a much greater chance of the sand caving in and being continuously discharged in large quantities by the air lift—a result to be avoided if possible, as it decreases the efficiency of the plant and introduces an element of danger. It is usual to fix a perforated end to the suction tube, which is done by drilling a large number of ½-inch to ¾-inch holes in a 3 or 4 feet length of tubing, and attaching a plug to the extremity. This strainer admits the sand and finer particles, but excludes the larger fragments of rock and stone which put in an appearance in most wells. The total area of the perforations should be at least five or six times the area of pipe section.

The depth at which air is introduced into the rising main is decided by the height of liquid in the well, and the known variations of level observed during bailing. A submergence at least equal to the lift must be given, but as it is quite impossible to say to what extent the level will fall during work, the point of egress is generally kept as deep as circumstances will permit, without lying too near to the bottom of the well.

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* Where the term "suction" is used in connection with the air lift, it must be understood that the expression has not the usual signification, but is used to distinguish the part of the tubes situated below the point where air is admitted into the rising main.

n the common system of air lift (Fig. 66), where the air is conveyed n the well in the annular space between two tubes, no special attacht is essential at the point where the air enters the rising main; but ne modification of the above system, used in Baku, the outer tube is

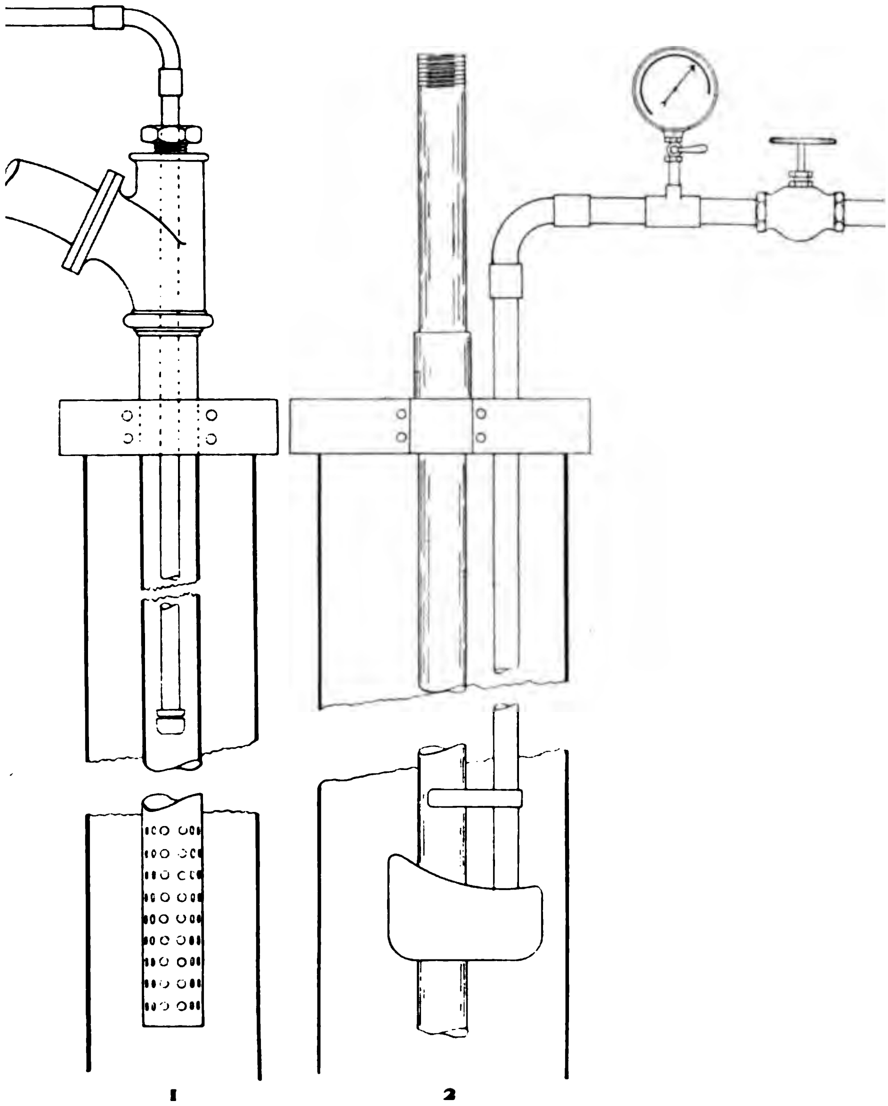


Fig. 65.—Air-lift Fittings.

1. Arrangement of air-lift fittings when air is admitted by a central pipe, the liquid rising between the tubes.
2. Arrangement of air-lift fittings when air is admitted by a side pipe, the liquid rising in the larger tube.

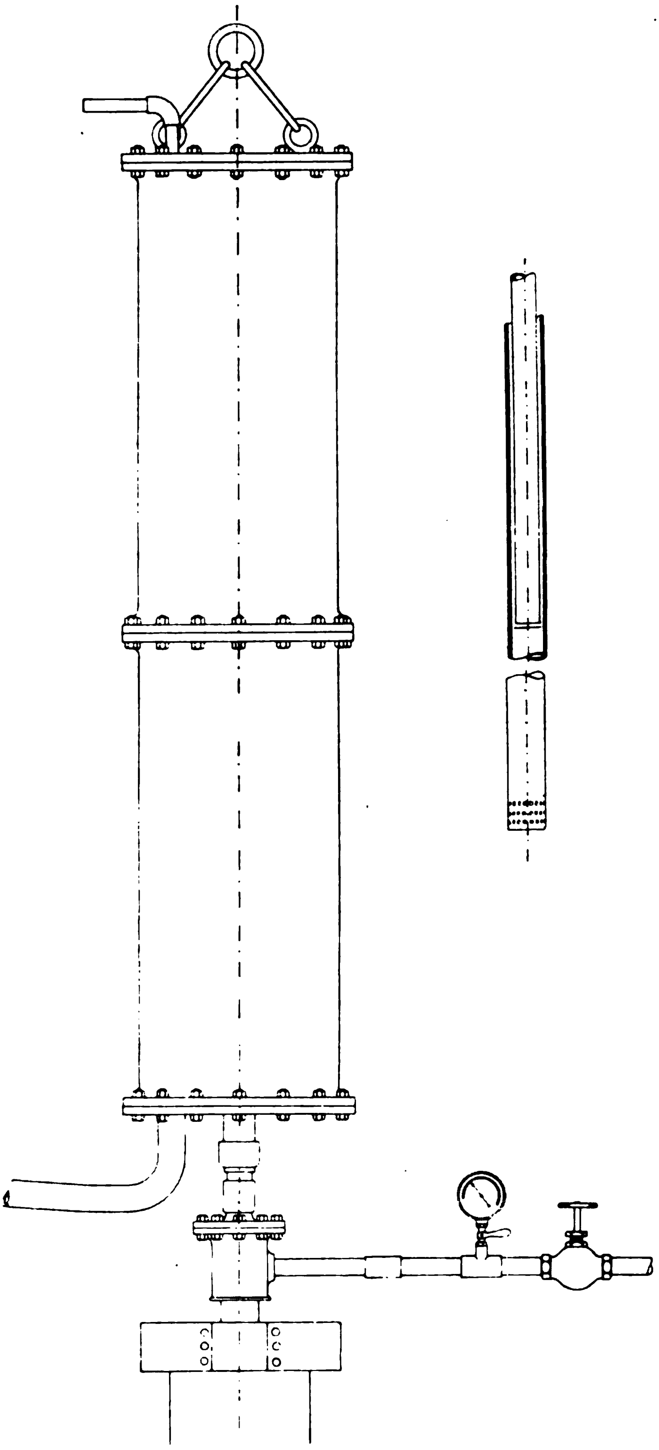
inished by a reducing socket at the point of air admission, and the suction ths are composed of a reduced size of piping. The inner line of tubes is designed with a conical collar which rests on a faced seating bored in the reducing collar, thus forming an air-tight joint. Above the collar, a perforated brass attachment of peculiar construction is attached, which admits the air into the inner pipe and directs it into a vertical direction. It is very doubtful whether any advantage is gained by such a device; indeed, in practice it has usually been found that a perfectly free inlet, unrestricted by any dispersing means, gives the best results, the air being apparently more suitable for operating the lift when in bulk than when divided into a number of separate jets. The arrangement of the tubes in the manner described above is open to another serious objection, namely, that the submergence of the inner tube, and consequently the point of air admission, cannot be altered without raising the whole of the tubes, exterior and interior—a work which occupies much time, whilst in the common system (Fig. 66) a few hours suffice to make the change.

The air tube and the rising main may be lowered side by side, and not one inside the other, if the dimensions of the tubes in stock are unsuitable for the latter method, but this also introduces the objection that the air inlet cannot be varied without the withdrawal of the whole of the tubing. When the lift is arranged in this way, the admission of air is secured by attaching, at a point previously calculated, a cored-out cast-iron or brass bracket, into which the rising main and suction pipe screw, designed with a protrusion on one side, where an accurately ground cup seating is prepared to receive a corresponding fitting at the end of the air pipes (see No. 2, Fig. 65). The air tubes are guided on to the seating by a firmly connected strap which encircles but passes freely over the tubes and collars composing the rising main, and allows them to be revolved around the main in a radius which corresponds with the position of the seating on the bracket. In a properly designed system there will be no pressure to resist at the point of air admission, as the air pressure and weight of external liquid will be exactly in equilibrium.

Surface Fittings.—The nature of the surface arrangements for admitting the air and conducting away the discharge leaves a large opening for individual ideas, but the general working of the apparatus is little affected by any special attachments, and the chief point is to have everything as simple as possible.

Many simple devices could be arranged, but although a right-angled bend leading the product away horizontally is the simplest plan that could be devised, it places a resistance in the path of the discharge, and unless very stout cast-iron bends are used, their life does not usually exceed a few weeks (sometimes only a few hours), on account of the wear they receive from sand mixed with the liquid. A good plan is to allow the liquid to discharge vertically into a vessel, placed directly over the outlet pipe, provided with a drain-pipe to convey the liquid away, and an exit orifice on one side to allow the air and gases to escape. A vessel of this description can be inexpensively constructed from an old boiler furnace-tube, which requires only a top and bottom cover, and holes bored at the desired positions (see Fig. 66).

Working of Air Lift.—When air is turned on to an air-lift system, several minutes elapse before any visible effects are manifested; but after a time the liquid may be heard rapidly ascending the tube, until it reaches the surface and is discharged in a full stream equal to the bore of the pipe. The



.—Showing Useful Surface Arrangement, and Point of Air Admission, here Air is conveyed down the Well between two Tubes, the Centre One ing employed as a Rising Main.

velocity of the jet rapidly increases and the fluid becomes more and more contaminated with air, until, with a violent outburst, the liquid is replaced by a still greater outrush of air alone. The initial violence is due to the raising of the column of liquid in an unaërated condition by a cushion of air which forms beneath it, and, where high pressures are employed and the discharge is led away horizontally, special precautions must be taken to prevent a serious accident from taking place at the first discharge. In one case, where a pressure of 550 lbs. per square inch was needed to start the lift, the 3-inch discharge pipes were forced back to an angle of 45° by the violence of the primary discharge. The first discharge, which entirely ejects the water formerly in the tubes, is followed by a few moments of quiescence, after which, in normal cases, a steady flow with but momentary intermissions commences.

The action is peculiar in character, as apparently the lift is not caused by the coalescence of a large number of separate bubbles of air disseminated through the liquid, but appears to be due to a succession of air bubbles separated by globules of liquid which follow each other so rapidly that the discharge takes the form of a series of slight impulses. The outlet, in fact, closely resembles the jet thrown from a pulsometer, which is also a rapid succession of small impulses.

The pressure required to start an air lift may be calculated by finding the pressure due to the weight of the column of liquid in which the air inlet tube is immersed, which column constitutes the dead resistance to be overcome by the air before performing work. No additional pressure is needed except a small amount to overcome friction in the air's passage down the tubes—which should be a negligible quantity in a properly designed system—and a small amount to overcome the inertia of the liquid, and put the column into motion, and to overcome the resistance of the tubes. This latter introduces a coefficient which varies with the specific gravity and the viscosity of the fluid, but the initial resistance is sometimes so great that the air will displace the liquid in the column below the air inlet and discharge into the well, before lifting the column above. The first discharge is followed by a fall of pressure, due partly to the removal of the before-mentioned inertia, and partly to a fall of level which, except in cases which will be mentioned later on, invariably takes place.

There appears to be a rather general but erroneous impression, that pressure plays an important part in the working of the air lift, and that the greater the lift the higher must be the pressure. The error probably arises from confusing the terms "pressure" and "volume;" but it should be noted that upon volume alone depends the working of the plant, the pressure being only supplied to overcome the resistance due to immersion necessary for the action. A fall of level is accompanied by a diminution of pressure, but a larger volume of air is needed to obtain the same results; and, *vice versâ*, a rise of level causes an increase in pressure, but a smaller volume of air to secure an equal output. This is true only within certain limits where the action of the air lift is assured, but when the submergence exceeds a certain amount, no further economy can be made, or when the level falls beyond a fixed point, no volume of air will induce continuous action. It must be noted that the air lift is a liquid "elevator" only, and is neither an "ejecter" nor an "injecter," as many people have considered it to be. The liquid in the tube is rendered lighter than the exterior liquid in the well, consequently the water flows from the well into the air-lift tubes to re-establish equilibrium, and the exterior pressure of air on the well water causes a continuous flow of liquid so long as the proper conditions last.

The pressure accurately registers the fluctuations of level in the well, when the conditions are normal and not affected by excessive gas pressure, etc., and a curve may be drawn from the records of the gauge, showing the hourly, daily, or monthly variations of level.

The following is a copy of the English patent granted to Pohlé on January 14, 1893 (No. 22,372), which shows the claims he makes for the use of compressed air for raising liquids:—

"The invention relates to the art of elevating water by compressed air, and consists in improved processes and apparatus whereby the compressed air is delivered in bulk into the lower end of the water eduction pipe, and the water and air are caused to ascend through the said pipe in distinct alternate layers of definite dimensions.

"The object of the invention is to successfully and practically effect the elevation of the water to a much greater height than has heretobefore been deemed economic with compressed air, and to avoid the results due to an intimate commingling of the air and water, as well as to dispense with all valves, annular spaces, and solid pistons. In accordance with my invention, the air is not directed into the water in the form of fine jets or bubbles, which would very rapidly commingle intimately with the water, but is delivered in mass, and the water and air ascend in well-defined layers through the eduction pipe.

"In the art of raising water by means of ejection it is essential to use a continuous and rapid current of steam or air, which by its velocity or momentum forms primarily a vacuum into which the water flows by suction; from whence it is secondarily drawn along by the induced velocity current of the steam or air thus used. In my process, which I term the 'air-lift process' or method, it is not necessary to create a vacuum at all, nor is it necessary to use a velocity current for the purpose of raising water; for its action depends primarily upon the gravity force of the liquid into which an eduction pipe is submerged, and secondarily it depends upon the elastic energy stored in compressed air when used in the manner to be described.

"I have discovered that when air of suitable pressure is allowed to enter, in a constant stream and in suitable quantity, into an eduction pipe, at or near its lower end when it is submerged in water, while its upper end rises above the water about the same distance that its lower end is submerged, that the compressed air thus introduced will at first expel the standing water from the pipe in an unbroken column free from air, and consequently by the continued inflowing of the compressed air under a pressure just sufficient to overcome the resistance of the water outside of the eduction tube, it will arrange itself in alternate layers with the water, while the latter flows into the lower end of the eduction pipe by force of gravity until it is discharged at the upper or exit end of the pipe. This alternate interposition of determinate quantities of air between the also determinate quantities of water elongates the entire column of air and water, thus facilitating, without materially adding to the weight of the column, the discharge of the water at a higher level than would be the case were these air sections or layers absent.

"I have also discovered that under the above-mentioned conditions, the compressed air will not escape through the water overlying it; and also that the water overlying the compressed air will not fall back through the underlying air while both are in upward motion; but find that the elasticity stored in the compressed-air layer, pressing alike in all directions, forms a temporary water-tight air piston, which lifts the water above it to its final discharge, without appreciable loss by leakage or so-called slippage, while this compressed-air piston, after having expended its elastic energy in work of lifting water, is dispelled with only a practically unimportant loss of power."

"At and before the beginning of the pumping, the level of the water is the same outside and inside of the discharge pipe (incidentally also in the air pipe), hence the vertical pressures per square inch are equal at the submerged end of the discharge pipe; when, therefore, compressed air is admitted into the air pipe, it must first expel the incidental standing water before air can enter the eduction pipe; when this has been accomplished, the air pressure is maintained until the water within the eduction pipe has been forced out, which it will be in one unbroken column free from air bubbles; when this has occurred, the pressure of the air is lowered or its bulk diminished and adjusted to a pressure just sufficient to overcome the external water pressure; it is thus adjusted for the performance of regular and uniform work which will ensue with the inflowing air and water, which adjust themselves automatically in alternate layers or sections of definite lengths and weights.

"It will be seen in the drawing that the length of the water column (shaded) and air (blank spaces), 1 and 1, are entered at the right of the discharge pipe, also that under the pressure of two layers of water, 1 and 2, the length of the air column 2 is 6·71 feet, and so on, the lengths of aggregate water columns and the air columns which they respectively compress are also entered on the right of the water pipe. On the left of the water pipe are entered the pressures per square inch of these water columns or layers; thus the pressure per square inch of column 1 is seen to be 1·74 lb.; that of 2, consisting of two columns or layers, 1 and 2, each 4·02 feet long, to be 3·49 lbs.; and that of 10, consisting of nine columns or layers of water, 1 to 9 inclusive, each 4·02 feet long, and one of 3·80 (viz. layer 10) feet in length, to be 17·35 lbs.; and the aggregate length of the layers of water is 39·98 feet in a total length of 91 feet of pipe.

"It will be noticed that the length of pipe below the surface of the water in the well is 35·5 feet, and that the difference between this and the aggregate length of the water layers (39·98) is 15·52 feet; that is, on equal areas, the pressure outside of the pipe is greater than the pressure on the inside, by the weight due to this difference of level, which is 47·65 lbs. for the end of the discharge pipe. It is this difference of 15·52 feet, acting as a head, that supplies the water pipe, puts the contents of the pipe in motion, and overcomes the resistance of the pipe.

"In general the water layers are equal, each to each, and the pressure upon any layer of air is due to the number of water layers above it; thus the pressure upon the bottom layer of air, 10 in the drawing, is due to all the

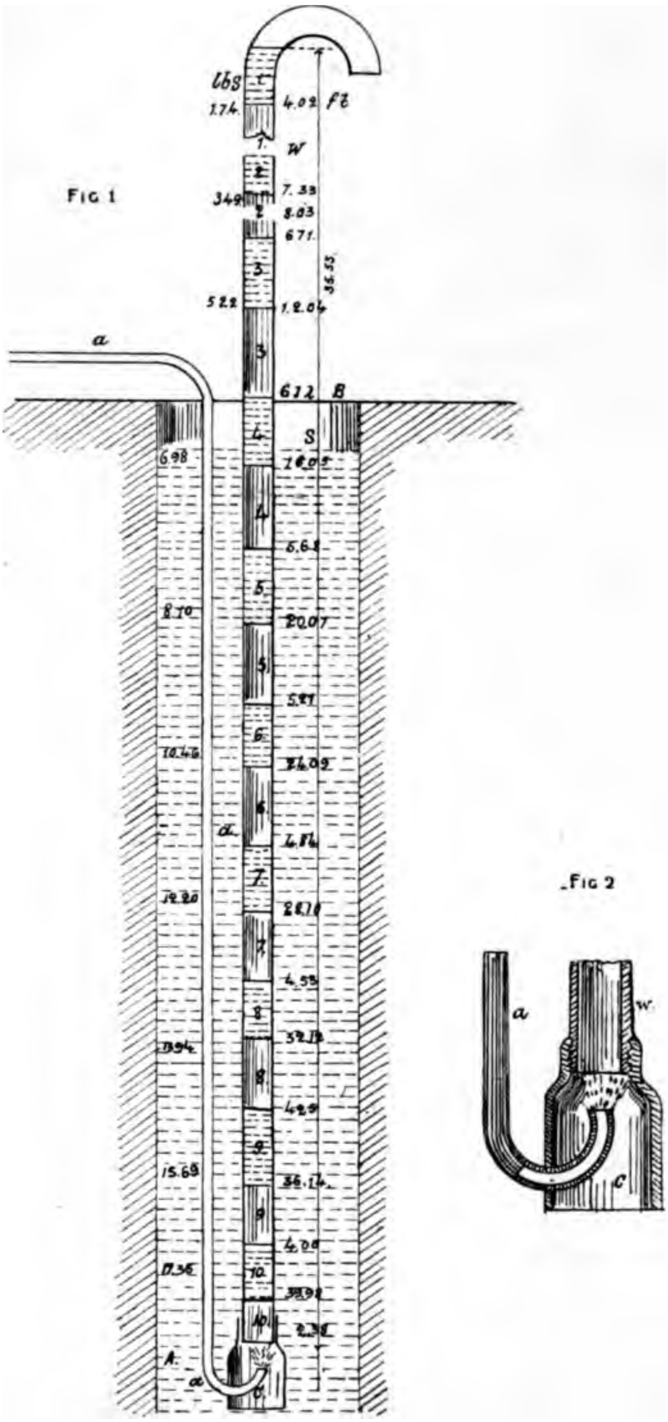


Fig 67.—Section of Pohlé's Air-lift System, illustrating Action.

layers of water in the pipe (17·35 lbs.); and the pressure upon the uppermost layer of air, 1, is due to the single layer of water, 1, at the moment of its discharge beginning, viz. 1·74 lb. per square inch; as this discharge progresses this is loosened until, at the completion of the discharge of the water layer, the air layer is of the same tension as the normal atmosphere.

"The quantitative relations of the air to water are determinable, but vary with the relations of submergence to lift, diameter of pipe, temperature and atmospheric pressure, and range from 1·5 volume to more volumes of normal air, compressed to an adequate pressure, for each volume of water raised by this process. The best efficiency is attained when the submersion is three-fifths of the total length of the eduction pipe.

"It is evident that the process above described is applicable to all other liquids besides water, such as petroleum oil, saline solutions, brewers' and tanners' liquors, sewerage, etc., and therefore I do not limit the invention to the elevating of water; neither do I confine the invention to compressed air alone for the purpose of raising liquids by this process, but claim any uniform body, such as natural gas and steam when used in oily liquids.

"Whatever the submergence or lift may be, in order to secure the desired continuous upward flow of the contents of the eduction pipe without stoppage or downward dropping of the same, it is necessary that the air, as introduced into the pipe, should be in quantity sufficient to form immediately upon its issue from the air pipe bubbles which will expand across to fill the eduction pipe from side to side, and make distinct piston-like layers entirely separating the portions of the water column between which they enter the said pipe.

"Where the bubbles are smaller than this, they will pass up through the water, and, while necessarily elongating the water column, will not exert the positive elevating power that my pipe-filling air layers, entirely dividing the layers of water from each other, do.

"The enlargement at the lower end of the eduction pipe I have found to be of advantage, not only as compensating for the space taken up by the air pipe, but where the mouth of the latter is well below the upper end of the enlargement as facilitating the formation of bubbles sufficiently large to make the desired pipe-fitting, piston-like layers rapidly and continuously following each other at very short intervals in the flow up the eduction pipe.

"When the body of water first standing in the eduction pipe has been forced up out of the latter by the compressed gaseous fluid used, the fluid pressure is preferably diminished, as indicated hereinbefore. In practice I so reduce the pressure to a point below the weight of the column of liquid which, standing in the eduction pipe above the point of entrance of the gaseous fluid, has been removed as stated."

The exact claims are then set forth as follows:—

"1. As an improvement in the art of elevating liquid, the process, which consists in submerging a portion of an open-ended eduction pipe in a body of the liquid to be raised, and continuously introducing into the liquid, within the lower part of the pipe, a series of bubbles of compressed gaseous fluid containing enough of the fluid to expand across the pipe and fill the same from side to side, forming pipe-fitting, piston-like layers at or just above the point of their entrance into the pipe, whereby the column of liquid rising in the pipe, after the forcing out of the liquid just standing in the latter is subdivided by the gaseous fluid into small portions before it reaches the level of the liquid outside the pipe, and a continuously upward-flowing series of well-defined alternate layers of gaseous fluid and short layers of liquid is formed and forced up the pipe, substantially as and for the purpose specified.

"2. As an improvement in the art of elevating liquid, the process, which consists in submerging in the body of liquid to be raised a portion of an open-ended eduction pipe having an enlarged chamber at its lower end, and continuously injecting into such enlargement, well below its upper end, gaseous fluid under pressure, to form bubbles in the pipe above the enlargement, large enough to extend across from side to side of the pipe proper, and form pipe-fitting, piston-like layers therein, interposed between and entirely separating well-defined layers of liquid in the pipe, substantially as and for the purpose described.

"3. As an improvement in the art of elevating water or other liquid, the process, which consists in submerging a portion of an open-ended pipe in a body of the liquid to be raised, removing the upper portion of the column of liquid within the pipe, and injecting into the latter, at a point well below the level of the liquid in which the pipe is submerged, gaseous fluid in quantity sufficient to form bubbles which will expand immediately across the pipe, and fill the same from side to side, and under pressure less than the weight of a column of liquid in the pipe extending from the point of entrance of the gaseous fluid to the level of the body of liquid surrounding the pipe, so that a continuous upward-moving series of alternate well-defined gaseous fluid and liquid layers will be formed in and forced up the pipe, substantially as and for the purpose described."

The Russian patent specification, granted by the Manufacture and Trade Department, in 1896, for 10 years, is only a copy of the above, translated as nearly as possible into the Russian language.

It will be seen, on perusing the patent specification, that Dr. Pohlé had a very fair idea of the working of the air lift when operated with water, although his theory of action is probably far from correct; but no suggestions are made as to its action when other liquids are employed.

The expansion of the air during the upward motion of the fluid in an air-lift plant naturally causes a constantly increasing velocity of the fluid as the surface is approached, the removal of which might be advantageous. Mr. Jos. Price has patented an arrangement to avoid this increase of velocity, and a much higher efficiency is claimed to have been obtained than in the ordinary air lift. In Mr. Price's installation the rising main increases in area as the point of delivery is approached—a result attained by inserting a slightly larger size of tubes at intervals towards the surface—and, as a result, the accelerating velocity of the fluid is counteracted, and the evils resulting from resistance to expansion and from a high velocity, and its consequent tendency to cause the formation of eddies, are partly overcome.

Size of Tubes and Rate of Discharge.—The common sizes of the discharge pipes for the air-lift service are 2 inches, 2½ inches, and 3 inches, which, under usual conditions, give as large an output of liquid as it is advisable to withdraw; the definite size being fixed by the character of the well. The actual amount of liquid which will be obtained when the apparatus is put into operation can never be foretold in oil wells, as it is dependent upon so many unknown factors which always appear and considerably modify all calculations; but the engineer may rely with certainty that, whatever he does, a surprise of some kind lies in store for him.

The rate of discharge is affected by—

(1) The variations of level of the liquid.
(2) The proportions of oil and water.
(3) The amount of sand.
(4) The quantity of gas.
(5) The specific gravity, temperature, and viscosity of the fluid.

(1) *The Variations of Level of the Liquid.*—As the working of an air lift nearly always causes a fall of level, it is usual to admit the air at a lower point than is needed for immediate requirements, otherwise a large loss of economy ensues from a fall of level. The best results are obtained by giving a submergence of 60 per cent. of the total depth, *i.e.*, air should enter the rising main at a point 20 per cent. deeper in the liquid than the direct lift from the level of the liquid to the surface outlet. If a well were 1500 feet deep, and the liquid stood 500 feet from the surface, the air would be admitted at a depth of 1250 feet, or 750 feet below the liquid-level, to secure the most economical working; but in order to counteract the effect of a probable fall of level, the point of air admission should be increased to 1300 or 1400 feet. With submergences of from 40 to 60 per cent., the outputs from different-sized tubes are approximately as follows:—

2 inches . . .	150 to 270	cubic feet per hour
2½ inches . . .	260 „ 550	„ „ „
3 inches . . .	550 „ 800	„ „ „

There is a point, varying with the quality of the liquid and the size of the piping, beyond which the air, if admitted, seeks an exit in the well by acting downwards, in preference to overcoming the inertia of the fluid and the friction of the tubes, and lifting the column of liquid above, and it has been found necessary in practice, when dealing with oil, to keep the point of admission of air from 50 to 70 feet above the bottom of the suction tube in ordinary systems. The submergence should not be deeper than is found to be advisable, for it is obvious that the higher pressure, as a consequence, leads to a loss of economy in the working of the plant without conferring any advantages.

When the output is composed chiefly of water, a fall of level which reduces the submergence below 50 per cent. converts the action into an intermittent one, and the discharges partake more of the form of the first flow when an air lift is started. The periods of rest separating the flows range from 1 minute to 3 minutes, and are quite free from any escape or discharge of air. The discharges occupy from 1 minute to 3 minutes, according to the supply of air and the level of the liquid, commencing with a full-bore flow of unaërated fluid, but gradually becoming more and more aërated until a violent outburst of air and spray completes the action. This peculiar intermittent action of the air lift is rather strange, for although air is supplied without cessation, the apparatus remains in a state of perfect quiescence for several minutes. What actually takes place can only be a matter of conjecture, but the air before each discharge apparently forms a pad or cushion near its inlet, and whilst lifting the column of liquid overhead bodily, or to a limited extent aërating the lower portion, the admission of additional liquid is prevented, and that present in the suction is driven downwards into the well. This peculiarity was discovered by confining the mouth of the bore-hole, when it was observed that a blast of air and gas reached the surface each time a discharge commenced, and that a suction action, indicating a fall of level, set in during the periods of rest.

The escape of such large volumes of air after each expulsion of liquid led to some experiments being conducted to ascertain what economy could be effected by supplying air intermittently, and utilizing the natural expansion of the air to perform useful work, where there was a low level of liquid. A series of trials made in a well with a submersion of from 30 to 35 per cent., demonstrated that a reduction of only 5 per cent. in the output occurred with a consumption of 60 per cent. of the air formerly used, thus creating an economy of about 36 per cent. At first the air valve was operated by hand, but afterwards a permanent automatic device was attached to obtain this result. When regulating the admission of air by hand, the most economical results were obtained by closing the inlet-cock a short time before the liquid reached the surface, and opening it again towards the end of the flow, but with the automatic contrivance, the expulsion of the liquid was employed to actuate the air cock, which, though somewhat delayed in opening, did not greatly alter the final economy. Intermittent action introduces a feature which is objectionable, but still, results can even then be obtained which cannot be approached by bailing.

The working of the apparatus, after the air supply is shut off, is conclusive evidence that the action is not dependent upon the pressure.

That the bulk of the fluid is expelled in a perfectly unaërated condition at the first discharge of an air lift, and that the expulsion is due to the formation of a piston of air beneath it, was shown in one example where the tubes were accidentally lowered into a clay sediment at the bottom of the well. Almost immediately after the air had been admitted into the tubes and the pressure reached but a few pounds, the liquid commenced to be expelled in a steady stream by the displacement of the liquid in the air tubes by the air, and it was nearly 10 minutes later that the violent discharge due to the ascent of the air piston took place. After the primary discharge, before which the pressure reached 500 lbs. per square inch, the gauge registered only 50 lbs., proving that the rising main had been almost emptied by the first admission of air, the plug preventing the refilling of the space. Eventually the liquid gradually rose, and the pressure steadily increased until a pressure of 450 lbs. was reached and normal action set in.

The diagram (Fig. 68) is prepared from the data furnished by a very deep well which yielded water and oil, and offered exceptional opportunities for experimenting. The details were as follows:—

Total depth of well . . . . = 1547 feet
Total depth of exterior or discharge pipe (3 inches) = 1540 ,,
Depth of air admission . . . . . . = 1247 ,,
Level of liquid in well (lift) . . . . . = 140 ,,
Submergence on starting . . . . . = 1107 ,,

It will thus be seen that a submergence of nearly eight times the lift was given in the first instance, but the production was not greater, nor the consumption of air less than when there was a 60 per cent. submersion. Below 50 per cent. the curve shows the rapid fall of discharge, notwithstanding an increase of 25 per cent. in the amount of air admitted at the 50 per cent. submersion line.

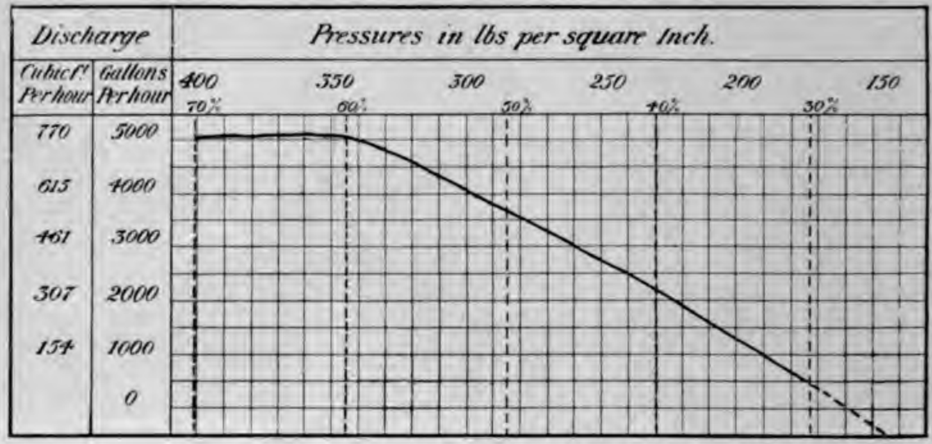


Fig. 68.—Diagram showing Output of Well operated by Air Lift at Various Submergences and Pressures.

The ratios of liquid raised to air consumed at different submergencies in this particular example were—

With 70 per cent. submersion 11·75 cubic feet free air to 1 cubic foot fluid
,, 60 ,, ,, 11·75 ,, ,, ,, ,, ,,
,, 50 ,, ,, 14·8 ,, ,, ,, ,, ,,
,, 40 ,, ,, 26·0 ,, ,, ,, ,, ,,

The diagram is merely approximate, as the outputs measured at different times at the same pressure exhibited considerable variations, owing to proportion of sand, percentage of oil, amount of gas, etc.; but the curve—or rather the line—represents a mean of many measurements. It will be observed that the line (if continued) intersects the zero line just below the 30 per cent. submersion point. Intermittent action commenced between the 40 per cent. and 50 per cent. submergence lines, although the position varied greatly, and was affected by the same conditions as already mentioned.

(2) *The Proportion of Oil and Water.*—The action of an air lift is largely influenced by the proportion of oil mixed with the water raised, and varying proportions considerably alter the amount and nature of the flow. In most wells where there is constantly a proportion of water present, the discharge is continuous so long as water only is expelled, but as soon as the proportion of

oil exceeds about 30 per cent., an intermittent action is developed without any difference of pressure being registered. The flows, following the periods of quiescence, commence with a stream of almost pure oil in an unaërated state, but the ejected fluid becomes more and more contaminated with water until, at the end of the discharge, water alone is present, the action being, in fact, converted into one similar to that which accompanies a fall of level as already described. In some cases the reverse of the above has been observed, the presence of a larger proportion of oil converting an intermittent action into a continuous one; but where this has occurred the fluid has been expelled in a state of spray, which suggests that the air lift has temporarily been converted into an air ejector. Each well appears to possess some peculiarity which owes its origin to special characteristics which cannot be foretold, and whilst some discharge oil in the form of a spray only, and give but a nominal output, others, under equal conditions of submergence, deliver almost pure oil in a constant pulsatory manner.

Gas plays a very important part in deciding the nature of the working of an air lift, as will shortly be explained; but the great difference of efficiency is made very apparent when comparing extremes working under almost identical circumstances. A 2½-inch delivery pipe with a 60 per cent. submergence has been known, in Baku, to give as much as 20,000 poods of *oil* a day with practically no water, and the same arrangement of plant in another well of equal proportions has yielded but 10,000 poods of liquid, chiefly oil. The consumption of air is just as remarkable, for whilst there are examples of one volume of liquid being raised to every eleven volumes of air supplied, fifty volumes of air are needed to perform the same work in other wells similarly designed.

Water mixed with from 5 to 10 per cent. of its volume of oil produces an emulsion specially adapted for raising with compressed air; and when the liquid, as occasionally happens, presents itself in this proportion, the rate of discharge at a fixed level is at once increased by 15 to 30 per cent. without extra consumption of air. It may be that this particular mixture contains just sufficient lubricant to diminish the friction in the tubes and so increase the efficiency, and not sufficient oil to form a viscous solution and reduce it. Advantage has been taken of this characteristic in several instances by admitting a small quantity of oil into the suction, which object is attained by drilling an inlet hole into the suction pipe some 20 to 30 feet from the bottom, for as oil nearly always reaches to this point, a small proportion is introduced into the water drawn from the bottom.* When gas is present in only small quantities, and the composition of the mixture at the point of air admission exceeds 25 per cent. of oil, the liquid is sometimes converted into a strange substance having the consistency of vaseline, and is ejected in congealed grey masses with considerable violence from the discharge pipe, the friction being so great that quite a roar is created in its passage upwards along the tubes. The formation of this emulsion appears to be due to the intimate admixture of a suitable proportion of air, water, and oil, under the influence of a powerful churning motion; but after lying for only a few moments in the chutes, the substance usually liquefies and flows away. In some cases, however, an emulsion of the above description is formed in large quantities, which retains its curious character for many days, and it is only after a prolonged settlement in reservoirs that the associated water disengages itself, and the oil returns to its normal condition. The formation of this material in large quantities at Bibi-Eibat led the Russian Petroleum and Liquid Fuel Co. to initiate a modification of the air lift, by which oil and water might be abstracted separately and alternately by varying the point of admission at frequent intervals (see note, p. 299). This arrangement has the desired effect, for no emulsion is formed when the proportion of oil is large, nor is it produced when the proportion of water is large. Some fears were entertained, when compressed air was first introduced, that the agitation of the air with the oil might injure its qualities or entirely alter its character, but although the peculiar emulsion described above is *sometimes* formed, it apparently only occasionally depreciates the quality of the petroleum. In some few instances reports have shown that an emulsion composed of 30 per cent. of oil, the remainder water, was constantly discharged, which did not separate even after settlement for weeks in spacious tanks.

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* See note on p. 299 for explanation.

(3) *The Amount of Sand.*—It has been frequently stated by the opponents of the air lift that sand could not be raised by its aid, and that plugs were sure to form which would render the system valueless, and, were a fountain to blow, the inrush of sand as a consequence would choke up the apparatus and lead to a tedious fishing operation to recover the embedded tubes. Experience has proved the reverse, and in most cases the air lift has been found to be one of the most effective and expeditious methods of cleaning out sand yet introduced. The air lift cannot be recommended for wells which are liable to spout and to yield periodically enormous volumes of sand, but if by its employment a greatly increased output is assured, there is no serious objection to its use even then, if certain precautions are taken.

It is a misfortune if a well blows very strongly, as there is danger of the tubes being buried in sand and the action stopped, but, in most cases, this can be prevented by supplying an increased volume of air, and not reducing the amount until a normal discharge is started. In a well 10 inches in diameter, to which the air lift was applied, fountains played for several minutes many times a day, each being followed by a heavy sand plug, which was expelled in such volumes that the fluid was composed of over 50 per cent. of sand. For one hour after the spouting, this thick, heavy solution was raised, necessitating the employment of two or three men to remove the sand from the settling tubs. In two cases the author has seen a fall of pressure from 200 and 500 lbs. respectively to 50 lbs. after the first discharge, due to the immersion of the main tubes in a plug at the bottom of the well; but in each case the obstruction of sand and clay was ultimately eased, and the ejected fluid was so thick for a time that it would not flow in an inclined chute placed for its reception. Rivets, stones, and pieces of clay have frequently been raised by the air lift, and in one well a thick mass of sand and clay was expelled for two hours before the plug was thoroughly loosened and normal action commenced. When sand is present in very large quantities, the working of the air lift is modified, but 10 to 15 per cent. of sand does not seriously diminish the efficiency.

A clay plug is the most undesirable material to meet with in a well, its impervious qualities preventing the percolation of water or oil through it, and this has been the cause of several failures where the air lift has been installed.

In one well at Bibi-Eibat, which spouted soon after the starting of the system, a sand plug rose and buried a large number of the air-lift tubes, but after the cessation of flow the lower part of the sand plug was cleared and the air lift continued to work beneath the plug, which formed a solid core in the well casing.

(4) *Quantity of Gas.*—The natural gas pressure of the well largely affects the economical working of the air lift, and introduces factors which considerably modify the engineer's calculations. When a productive well has been working for a few days and yielding a fair output, the gas generally increases, and has the effect of reducing the weight of the column of liquid. Notwithstanding a rise of level accompanying the higher gas pressure, the gauge invariably registers a lower pressure, and it will often be discovered that the air supply may, with advantage, be reduced. In one extremely gaseous well, where the air-lift was in operation, the liquid fluctuated between 900 feet from the surface and actual overflowing, but a rise of level was not attended by an equivalent rise of pressure, and the approach of a fountain was only recorded by a small increase of pressure on the gauge. When the well was actually flowing the gauge registered only 240 lbs. per square inch, whilst the actual pressure due to that weight of oil, *without gas*, was a trifle under 500 lbs., the gas consequently having the effect of halving the weight of the column of oil.*

In wells which give a handsome yield of oil, and are of a decided gaseous nature, the recorded pressure ranges from 20 to 30 per cent. less than the calculated amount, when the specific gravity of the oil is taken into account.

Recognizing to what an extent gas exerts a power in influencing the action of the air-lift, the question of utilizing this energy to perform useful work naturally suggests itself. In 1899, attempts were made in a gaseous well of the European Petroleum Co. to utilize the natural gas to assist the compressed air in its work. A thick wrought-iron flange, through which the compressor tubes passed, and to which they were securely attached by suitable means, was fixed on the mouth of the bore-hole, thus preventing the escape of the liberated oil gas. When, however, the escape-valve fitted on the flange was closed, the gas found an exit through numerous faulty rivet-holes and joints in the well casing, and no practical benefit was derived from the attachment; but if good screwed casing were employed for lining the well, this difficulty would be overcome, and the gas successfully harnessed and made use of. In Chapter VIII., mention is made of an arrangement to encourage a well to flow by restricting the outlet of the gas, and it is probable that most economical results could be obtained by the combination of a packer and compressed air with the same object. After once getting such a system to work in a good well, the natural gas, almost unaided, would keep up a continuous flow; but, in any case, the addition of only a small volume of air would be required to induce a constant stream, and prevent the formation of a plug, which invariably collects in Baku wells without the assistance of extraneous power.

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* The pressure gauge is always placed on a pipe between the air main and the air-lift tubes, and the regulating cock is fixed between the air main and the gauge.

In very gaseous wells the author has several times seen the air-lift tubes throwing oil periodically before the plant was completed and any air admitted into the service; the gas emerging from the confined space of the small tubing, carrying the oil with it, and causing a miniature fountain, whilst in the well casing the gas disengaged itself before the oil reached the surface, and prevented a fountain. This fact serves to show what a small volume of air would induce a constant flow of oil from wells where the whole of the gas was directed into the discharge pipe of an air lift.

The air-lift discharge from gaseous wells partakes of different forms, and whilst in some cases the flow is steadily maintained without interruption, in other wells the action is intermittent, or the fluid is ejected in a light spray; but great care is needed in adjusting the supply of air, and the air-cock must be manipulated until the best results are obtained with the least consumption of air.

In one well which occasionally spouted when the air-lift system was at work, and where considerable variations of level were indicated by hourly changes of the pressure, the experiment was tried of inducing a fountain artificially at regular intervals. A heavy stop-cock was attached to the outlet of the discharge pipe, which, when closed, forced the air to find the only other exit possible—through the bottom of the suction tube into the well. Each time the cock was closed a fountain occurred, which yielded from 300 to 400 poods of oil; but directly the well exhibited signs of flowing, the cock was opened, and the action of the air lift recommenced to clear away the sand plug which rose on each occasion. This operation could only be repeated with success once every 2 hours, and attempts made before the expiration of this period failed to induce a fountain.

(5) *The Specific Gravity, Temperature, and Viscosity of the Fluid.*—The working of the air lift is to a varying degree influenced by the three above-named qualities of the liquid, but changes of one cause changes of the others, the three being intimately associated. An increased or diminished temperature will alter the specific gravity and the viscosity of the oil, and the specific gravity and the viscosity of oils bear a relation to each other irrespective of temperature. The temperature of the oil in the Baku wells lies between 75° and 95° Fahr., so that it is never low enough to produce congelation; but heavy oils exceeding 0·900 specific gravity, when unadulterated or only slightly mingled with water, lead to an immense amount of friction in their ascent, and greatly impede the velocity of flow of the fluid, and cause an erratic working of the air lift.

In wells which alternately yield water and oil (a frequent type in Baku), the change from water to oil can be at once predicted by the sudden variation in the action of the lift, although the oil does not reach the surface until several minutes later. The rate of discharge is frequently reduced 50 per cent. by the replacement of water or a mixture of 5 to 10 per cent. oil with water for pure oil, or a solution exceeding 50 per cent. of oil, which proves the extra difficulties encountered when oil is present. A return of water after a somewhat desultory period of oil ejection can likewise be at once foretold, in this class of well, before water appears at the outlet, for the improved action near the point of air admission causes the oil present in the upper part of the tube to be expelled for several minutes, in a heavy stream, by the more easil moved column of water beneath it. Where a submergence of nearly 60 per cent. is not maintained in the presence of pure or almost unadulterated oil, the air seems to disengage itself, find a passage through the liquid, and discharge the oil in the form of a fine spray instead of raising it bodily in well-defined pistons, as in the case of water. This alteration in the form of discharge, due doubtless to the viscous nature of the fluid, is sufficient to explain the considerable difference of yield which is generally experienced.

The water raised from some wells by the air lift has been observed to reach a much higher temperature than when raised from the same wells by bailing, the result of which is to assist the action of the air lift by lightening the column of fluid in the rising main. Friction alone will not account for this unexpected rise of temperature, for this feature is only developed in occasional wells, and it seems probable that the heat is the result of an active chemical action taking place between the air and dissolved gases in the water. In one or two cases the discharges were accompanied by volumes of steam, the temperature exceeded 90° Fahr., and a strong sulphurous odour pervaded the immediate vicinity. The effect of the expanding air is to reduce the temperature of the fluid with which it comes in contact during the process of expansion, and unless some chemical reaction is accepted as an explanation for the abnormal heat, the peculiarity cannot easily be accounted for.

Recording Gauges.—By attaching a recording gauge near the point of air admission to an air-lift service a diagram is produced giving an exact record of the fluctuations of pressure, and consequently of the level of liquid in the well. Such diagrams are exceptionally useful for tracing the effects of the air lift on the well, and give the engineer a full graphic description of the day's working.

Diagram A (Fig. 69), below, shows a bad day's operation, where a constantly rising plug of sand and stones continually choked the inlet perforations on the suction length of the air-lift tubes, causing an intermittent action to set in, the contents of the rising main being partly emptied at each discharge, and only replaced gradually by fluid admitted with difficulty through the plugged strainer. The frequent fall from the normal-pressure line to about one-third, following each expulsion of oil, is clearly represented on the diagram.

Diagram B shows a steady day's work in the same well after the total removal of the excessive plug which had previously impeded the free action of the plant.

It is needless to add that the gauge must be placed between the regulation air cock and the well, to obtain a true registration of the variations of pressure.

Rate of Removal.—The rate at which liquid should be raised from an oil well depends entirely upon circumstances, for where much water gains access to the bore-hole—and the chief object of the air lift is to overcome this —very large quantities may often be raised. In wells of average yield the rate of removal should be such that the necessary level for the submergence is maintained, and the sand is not drawn in by the stream in more than moderate quantities. This varies much in different wells; but where the upper water has been properly excluded and there is no more than a nominal quantity admitted with the oil, a good practice is to arrange for a removal of 600 to 800 poods (2400 to 3200 gallons) per hour, equivalent to 14,000 to 20,000 poods a day. A well situated on fairly prolific ground will yield this amount without unduly exciting the gas and sand or lowering the normal level; but an increase may induce an unusual accumulation of sand around the tubes, and cause them to choke. Upon this vexed point a deal of controversy exists, which really, in the end, comes back to the subject of fast bailing, discussed in Chapter X.; but comments, which have from time to time appeared in the Russian papers, throw doubt upon the benefits which are said to be derived from compressed air. It is stated, by opponents of the air-lift system, that it has the effect of drawing in water and spoiling the wells, and instances are quoted where wells have developed water after the installation of compressed air. The arguments are based upon the rapid removal of liquid and reported lowering of level which encourage the admission of water. In the first place, water should not be drawn in under any circumstances if the well is securely cemented. But supposing that exclusion is not perfect, and water may follow a fall of level; also suppose the air lift to be

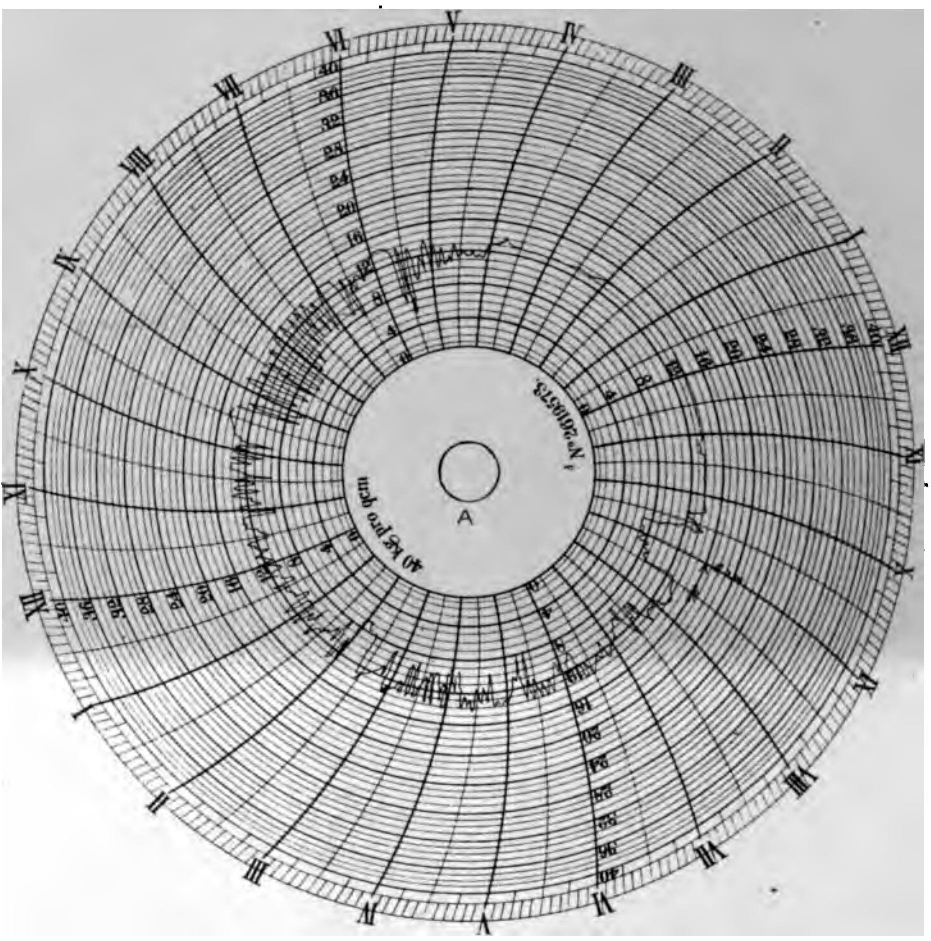
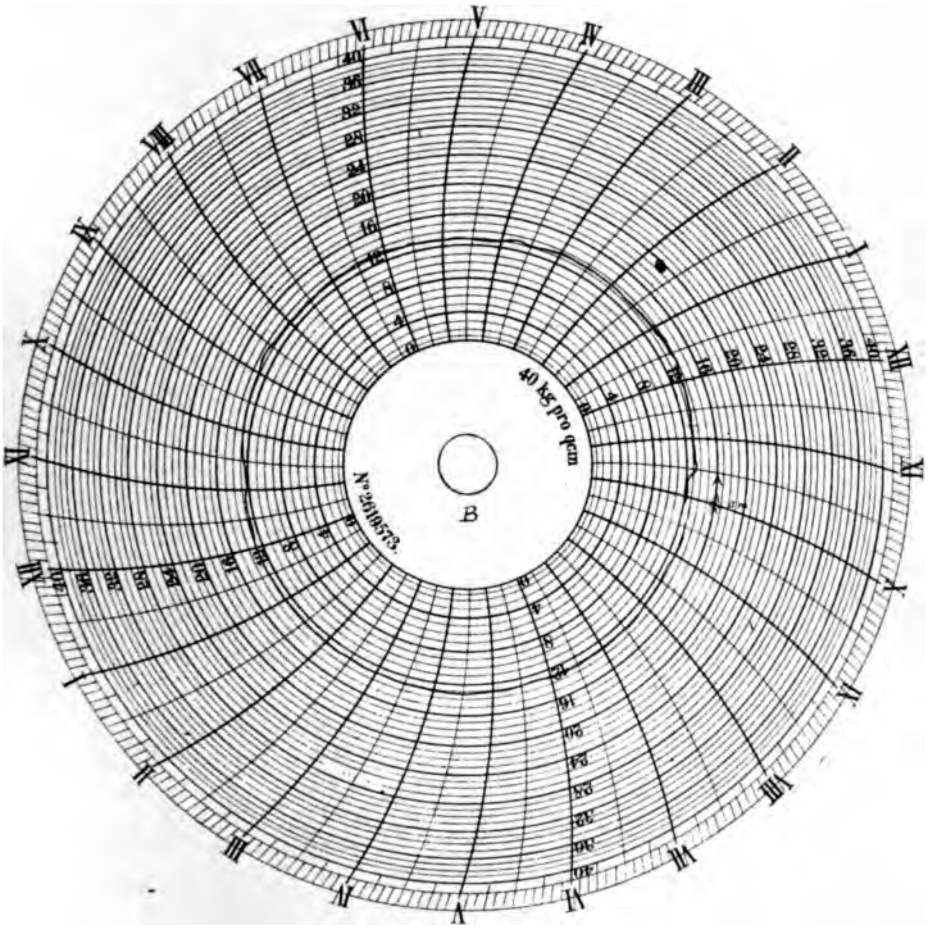


Fig. 69.—Diagrams from Recording Gauge attached to A. Showing irregular action due to sand plugs.

installed with a submergence of 60 per cent. given to the eduction pipe;—what is the result? No oil can be obtained until the water is entirely removed from the bore-hole; a fall of level of only 10 per cent. diminishes the rate of discharge, whilst a fall of 20 per cent. probably halves the output, and a still greater fall renders the system almost inoperative. These features should recommend compressed air as the least dangerous method of raising oil yet introduced, and the fact that no oil can be raised until the well is drained of water should commend the air lift to every one connected with the raising of oil.



Air-pipe connected with a Working Air Lift in Oil Well.
B. Showing normal action when only ordinary quantity of sand present.

Compressed air gives a means of raising a much greater quantity of oil in a definite period, especially from wells of small diameter, than by bailing; and it is to the interest of all producers to get the greatest quantity of oil in the shortest time. The application of the air lift will not increase the total output of the wells, except, perhaps, where water is present, or where neighbours are actively drawing oil from the same oil stratum; but it will considerably shorten their productive lives, so that when comparisons are made, the statistics must refer to production, and not to length of life. A well of small diameter may yield a million poods annually for 5 consecutive years, and then dry up, or be flooded; but the same well, if operated by compressed air, might, under favourable circumstances, produce the 5,000,000 poods in 1 year or 1½ year, but because it then falls off to water it cannot fairly be argued that compressed air is the guilty agency.

For example, a well of the Russian Petroleum and Liquid Fuel Co. at Bibi-Eibat, which had in 2½ years given, by bailing, about 1,500,000 poods, produced 20,000 poods daily when fitted with the air lift, and gave over 2,500,000 poods in 5 months. The well then got flooded, but as 4 years' ordinary bailing production had been abstracted in 5 months, the loss of the well could scarcely be placed to the discredit of the air lift. A well belonging to Mantasheff and Co., also at Bibi-Eibat, which formerly gave a few hundred poods of oil daily by bailing, yielded 20,000 poods a day when worked by compressed air, and had up to the end of November, 1902, produced 5½ million poods in 9 months. Two wells at Romany, belonging to the same company, which jointly gave 500 poods a day, produced from 6000 to 8000 poods when installed with the air lift. There are also many wells in the Saboontchy district which have had their production increased from 1000 or 2000 poods to 8000 or 10,000 poods a day by the adoption of the air-lift plant, so that the value of this principle can scarcely be dismissed in an offhand manner.

There are many examples of wells which have derived no advantage from the employment of compressed air because of the admission of water in almost unlimited quantities, but it must be remembered that most of the wells—or it might truly be said all, with the exception of the Russian Petroleum and Liquid Fuel Co., and the Baku Russian Oil Co.—given over to the air lift have been those which gave no production of any consequence by bailing, and would in the ordinary course of events have been abandoned or deepened. There are also instances of borings where water has been removed by the air lift without cessation for 2 months and even 4 months, and then oil obtained in remunerative quantities.

Assuming a rate of discharge of 600 to 800 poods per hour, the most suitable for average wells, it will be found that with a 60 per cent. submergence, a 2½-inch pipe will deliver this quantity, the actual amount being decided by the particular features of the well and the supply of air. 2½-inch discharge pipes are generally used for the air lifts in the Baku oil fields, although both 2-inch and 3-inch are employed to a small extent. It is often found that when an air lift replaces bailing in a well of small diameter, the amount of water raised is the same as before, but the extra liquid expelled is oil, thus explaining the former absence of production.

Consumption of Air.—The consumption of air in different wells, similar in most respects, varies enormously, and no reliable information can be offered as to the volume of air needed for any particular well. When 2-inch, 2½-inch, and 3-inch tubes are employed, the consumption of air for a maximum output deviates between 100 and 250 cubic feet of free air per minute, according to the submersion, etc., and the volume of free air used per cubic foot of liquid raised, ranges between 11 cubic feet and 50 cubic feet. When twenty-five volumes of air are consumed to 1 cubic foot of liquid lifted, the results are considered good, but the more usual proportions vary between thirty and forty-five volumes of air per volume of fluid. The supply of air into an air-lift service must be very carefully adjusted or a large loss of efficiency takes place; for this system will consume almost any volume of air that is admitted, to the detriment of its action. In water wells only several hundreds of feet deep a ratio of six to eight volumes of air per volume of liquid raised is often obtained with a 60 per cent. submergence, but experiments seem to demonstrate that such efficiencies are impossible with deep air lifts of the dimensions that are practicable. When designing an air lift with a 2½-inch or 3-inch discharge, capable of lifting from 1500 to 3000 gallons per hour, provision should be made for the supply of 200 to 250 cubic feet of free air per minute, as a reserve of power is always an error on the correct side, and prevents much future vexation.

The efficiencies of the air lift plants, when worked out from the above figures, vary from 8·5 per cent. in the worst cases to 40 per cent. in the best; the efficiency being reckoned as the ratio of the weight of water lifted from the level of liquid in the well to the surface, to the indicated horse-power of the engine driving the compressor.

The following details are from a well working with the air lift, which gave ordinary results:—

Depth of outer 4-inch tubes to bottom of well	1540 feet
Depth of inner 2½-inch tubes (air inlet)	1463 „
Working pressure	300 lbs.
Consumption of free air per minute	150 cubic feet
Liquid discharged per minute	6·25 „

Therefore one volume of liquid is raised for each twenty-four volumes of air supplied.

The compressor was of the compound double-acting belt-driven type with cylinders 14-inch and 7-inch diameter with 12-inch stroke, and ran at 75 revolutions per minute.

High-pressure cylinder indicated	8·57 H.P.
Low-pressure „ „	8·46 „
Total horse-power indicated	17·03 „

The steam-engine driving the compressor was a 14¼-inch × 18-inch double-cylinder, horizontal type, which also ran at seventy-five revolutions per minute. Indicated horse-power, 36·7. Therefore—

$$\frac{17\cdot03 \text{ indicated H.P. of compressor}}{36\cdot7 \text{ indicated H.P. of engine}} \times 100 = 46\cdot4$$

that is, 46·4 per cent. of the indicated horse-power is transformed into useful work, and 53·6 per cent. is used in overcoming friction, etc., on the engine and the compressor.

A pressure of 300 lbs. represents a submergence of $\frac{300 \times 34^{*}}{14\cdot7} = 693\cdot8$ feet,

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[*] 34 feet is taken as representing 1 atmosphere in this case, as the liquid was a mixture of heavy salt water and oil intimately mingled by gas. 14·7 represents the pressure of 1 atmosphere in lbs. per square inch under normal atmospheric conditions.

and $\frac{693{\cdot}8}{1463} \times \frac{100}{1} = 47{\cdot}4$ per cent. Therefore the direct lift is 1463 − 693·8 = 770 feet, and 396 lbs. (weight of liquid raised per minute) × 770 = 304,920 foot-lbs. = 9·24 horse-power, which is the actual theoretical power needed to raise this quantity of liquid. Therefore the total efficiency of the plant, disregarding corrections for temperature of liquid, condition of atmosphere, etc., is—

$$\frac{9{\cdot}24}{36{\cdot}7} \times 100 = 25{\cdot}18 \text{ per cent.}$$

The following are particulars of a well even more unfavourably situated for the use of the air lift, where the submersion was only 37 per cent.:—

4-inch exterior tube to	1243 feet
2¼-inch inner discharge pipe	1227 „
Working pressure (near)	170 lbs. per square inch
Liquid discharged per minute	5·5 cubic feet = 300 lbs.
Consumption of free air per minute . . .	240 „

Therefore one volume of liquid is raised for each forty-four volumes of air supplied.

The steam-engine driving the compressor indicated 48·048 horse-power when the above-named volume of air was being delivered.

The working pressure of 170 lbs. is equivalent to a submersion of approximately 450 feet in oil (and this was proved to be about accurate by lowering a small bailer down the well, and ascertaining the level); therefore the direct lift was 1227 − 450 = 777 feet, or only 37 per cent. submergence.

The theoretical power needed to raise 300 lbs. of liquid per minute to a height of 777 feet is—

$$\frac{300 \times 777}{33{,}000} = 7{\cdot}07 \text{ H.P.}$$

Therefore the total efficiency of the whole plant under these very unfavourable conditions was—

$$\frac{7{\cdot}07 \times 100}{48{\cdot}048} = \text{nearly 15 per cent.}$$

Cost of Air Lift.—The chief objection raised against the use of compressed air is its great cost compared with bailing, and it is the dread of this primary expenditure and the increased fuel consumption which prevent many firms from making a trial. The initial outlay for machinery and apparatus is about three times that required for a bailing well, and the consumption of fuel is from 50 to 100 per cent. greater than that of a large bailing well working under usual oil-property circumstances. Under the changeable local conditions, the consumption of fuel per cubic foot of free air compressed to pressures between 250 lbs. and 300 lbs. per square inch, varies from 0·016 lb. to 0·022 lb., or 16 lbs. to 22 lbs. of oil per thousand cubic feet of free air. A compound compressor with a capacity of 300 cubic feet a minute, at a pressure of 300 lbs. per square inch, consumes 196 to 260 poods of fuel per day of 24 hours, according to its distance from the boiler-house, etc., (the calculation being based on the assumption that one indicated horse-power is equivalent to the consumption of 4 lbs. to 5¼ lbs. of petroleum fuel per hour). The consumption of fuel in the example quoted on p. 273 was approximately 130 poods a day, assuming 5¼ lbs.

of fuel to be equivalent to one indicated horse-power per hour. When one volume of liquid is raised to twenty-four volumes of air at 300 lbs. pressure, as in the example mentioned, 1 lb. of fuel lifts 1·8 to 2·0 cubic feet of liquid, but when the proportion falls to 1 : 40, the fuel consumption rises to as much as 1 lb. to 1·2 or 1·25 cubic feet of liquid lifted. Table XXIII. has been prepared to show approximately the number of cubic feet of fluid raised by 1 lb. of oil fuel at pressures from 100 lbs. to 300 lbs. per square inch, and ratios of 1–10 to 1–50, 5¼ lbs. of fuel being considered the equivalent of one indicated horse-power.* Compressors are generally fixed near to the boilers, and in a proper station under the direct supervision of a mechanic, so that the figures in the table represent minimum outputs per pound of fuel, and the quantities might be increased by 15 to 25 per cent. under favourable circumstances. An average bailing well working under usual oil-property conditions raises from 3 to 4 cubic feet of liquid per pound of crude petroleum fuel.

TABLE XXIII.

APPROXIMATE VOLUME OF LIQUID RAISED PER POUND OF OIL FUEL, UNDER VARIOUS RATIOS AND PRESSURES, BY AN AIR LIFT.

Volumes of air to one volume of liquid.	Cubic feet of liquid raised per pound of fuel consumed. (5¼ lbs. = 1 I.H.P.)				
	100 lbs.	150 lbs.	200 lbs.	250 lbs.	300 lbs.
10	7·4	6·1	5·4	5·0	4·9
15	4·9	4·0	3·6	3·3	3·1
20	3·7	3·0	2·7	2·5	2·4
25	3·0	2·4	2·2	2·0	1·8
30	2·5	2·0	1·8	1·7	1·6
35	2·1	1·7	1·5	1·4	1·4
40	1·8	1·5	1·4	1·2	1·2
45	1·6	1·4	1·2	1·1	1·0
50	1·5	1·2	1·1	1·0	0·9

These figures alone, without any explanation, certainly put a bad complexion on the air lift, but the subject of cost cannot be dismissed without considering the extent of the benefits derived from its use, as already explained, and the increased production obtained. Almost the first experiment tried with the air lift by the European Petroleum Co. was in a well which gave 500 poods of oil a day by bailing, but the installation of the new system raised the output to 2500 poods a day. By increasing the fuel consumption by 100 poods (say 100 per cent.) a day, the production of the well was raised by 2000 poods (increase 400 per cent.). There are many examples in the Baku oil fields of wells in which the air lift has been fixed where the production has been doubled or trebled by its application, and many more where a purely nominal amount has been turned into a handsome output. An increase of 4000 to 6000 poods a day, or even 2000 poods, will give a very profitable return upon an initial expenditure of £2000 in fixing the necessary plant, whilst, with the exception of a maximum extra daily consumption of fuel of 100 poods, the working expenses are considerably less than by bailing.

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* See Chapter XII.

Diagram A (Fig. 74) in Chapter X. represents the effect of the air lift in one well, and needs no special explanation; and appended is a tabulated list of a few more striking examples.

Below are the results of eight wells successfully operated by compressed air, the particulars of which were kindly supplied by the managers of the Russian Petroleum and Liquid Fuel Co., the Baku Russian Oil Co., the Schibaieff Petroleum Co., and the European Petroleum Co.:—

Name of company.	Number of well.	Oil production by bailing.	Oil production by air lift.	Months air lift in operation.
Russian Petroleum and Liquid Fuel Co.	24	1,000–1,500	12,000–13,000	5
" " " "	39	5,000–6,000	20,000	4
" " " "	41	500	6.500	13
" " " "	35	2,000	5,000	13
Baku Russian Oil Co. . . .	41	700	6,000–7,000	25
" " . . .	83	1,500	5,000–6,000	13
Schibaieff Petroleum Co. . . .	4	600	6,000–6,500	
European Petroleum Co. . . .	22	500	2,500	

Utilization of Escaping Gases.—Compressed air offers facilities for utilizing the gases which are liberated from the oil in a way that cannot be simply arranged when bailing is conducted. By employing good screwed casing for lining the well, the surface may be securely closed, and the gases, which usually escape into the air, may be led away in tubes, or stored under pressure in suitable receivers for use with gas-engines or for firing boilers. If a packer is fixed and the whole of the gas diverted into the discharge pipe to assist the air in its work, a cover is not needed, and the disengaged gases from the expelled fluid may be directly employed for the same purpose.

In all cases the intense agitation set up by the intimate commingling of the air with gas-saturated oil causes the liberation of a large portion of the benzine and lighter gases, producing a very inflammable gaseous mixture of a high calorific value. By fixing a suitable vessel and exhauster at the orifice of the discharge pipe, the gases* may be withdrawn and pumped to convenient reservoirs, where they may be collected and stored under pressure for various requirements on the property. Very little has yet been done with the object of utilizing the waste gases, but there is little doubt that much greater use will be made of them for working gas-engines, firing boilers, supplying smiths' forges, lighting workshops and quarters, heating cooking-stoves and fire-grates, etc., in the future.

Low-lift Systems.—Numerous patents have been filed from time to time for improvements in the art of raising liquids from deep wells where there is a low level, for many of which a greatly increased economy is claimed. The schemes may be conveniently classified under two heads: (1) Those which divide the lift into a series of stages, each operated by an independent air supply; and (2) those which work by the displacement of a body of the fluid collected in a receiver at the bottom of the well. But in both cases an essential feature of the apparatus consists of valves, which will in the Baku district generally condemn the system. It is the entire absence of complications, and all fittings which can be affected by sand, sand and gas, pieces of rock, and particles of clay, which recommends the air lift for Baku use, and any arrangement composed of valves will, in a large percentage of cases, be unsuccessful.

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* The gases are naturally mingled with a large volume of air; but this, whilst rendering the handling of the gas more dangerous, does not detract from its value as a source of power, as, in any case, air has to be mixed with the gas before combustion can take place.

In Grosny, low-lift processes could be employed with success, because the sand is almost infinitesimal in quantity; but there is, in most cases, not the same need for compressed air as at Baku, and its application would probably be found to be more expensive than bailing, whilst it would not improve the yield. The only low-lift system which has yet been tested in Baku (1903) is Stirling's patent, which consists of a column of tubes reaching to the bottom of the well, the lower submerged portion of which has an increased diameter. A short perforated pipe forms the strainer, and upon the junction socket connecting this with the enlarged part or receiver sits a ball-valve, which opens inwards from a seating, and admits the liquid from the well. Inch pipes inserted inside the rising main convey the air to a point immediately above the valve, and when air is admitted the ball-valve is forced upon its seating, and the liquid enclosed in the receiver is expelled upwards to the surface. The bulk of the liquid is ejected in an unaërated state, but towards the end of the flow a violent expulsion of air occurs which completes one action. The discharge is made to actuate a device which causes the air to be shut off immediately the liquid reaches the surface, and an ingenious appliance renders it possible to regulate the time after each successive discharge by readmitting the air after a pre-arranged interval. In low-lift systems a much cheaper type of compressor may be used, as the pressures are low, but the volume of air used is great.

Compressors.—The type and make of compressor best adapted for the oil-field conditions are subjects for careful consideration before expending large sums on new machinery, for, as no Russian-made compressors suitable for high pressures can be purchased, it is necessary to order those of foreign manufacture, which are subject to very high import duties. Weight, therefore, is an important factor when choosing a compressor, and it is partly on account of their massive construction that direct-driven steam compressors are avoided. The compressors should be of good workmanship, and combine simplicity with efficiency, for a complicated and intricate machine would quickly meet its doom in the hands of the usual unskilled attendants.

Belt-driven compressors conform most closely with the local requirements for the following reasons:—

(1) They are much less complicated than direct-driven steam ones, and are more easily cleaned and repaired.

(2) They are self-contained, and more easily removed and re-erected in another locality.

(3) They admit of being driven by steam-, oil-, or gas-engines, electric motors, or other power which the oil proprietor may have in stock.

Air compressors for high pressures become very expensive, and, as in most cases, the working pressures do not exceed 300 lbs. per square inch, they are usually ordered to stand this work, but are guaranteed to work up to 450 lbs. for a short time.

The capacity of the local belt-driven air compressors has been decided by the power of the common bailing steam-engines with which every oil producer is provided, and as the ordinary 14-inch × 18-inch or 14½-inch × 18-inch double-cylinder engines develop, with 50 lbs. steam pressure, 75 to 85 H.P. easily, compressors of 300 cubic feet of free air per minute have been chosen.

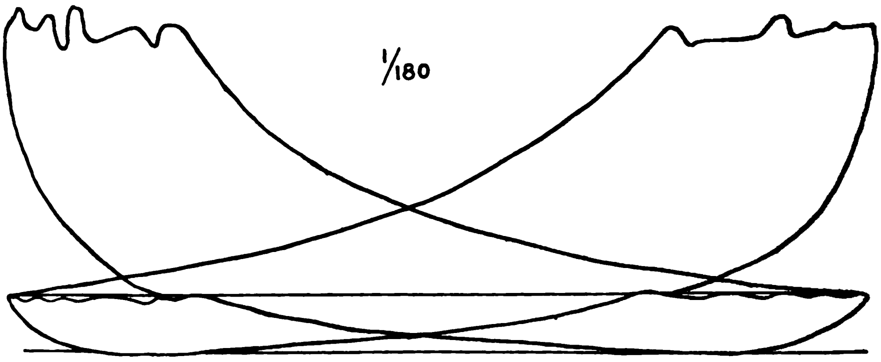

Fig. 70.—Combined Diagrams of Two Cylinders of Ingersoll-Sergeant Compound Compressor.

High-pressure cylinder, 14 inches diameter.
Low-pressure „ 7 „ „
Working pressure, 300 lbs. per square inch.
Average pressure H.P. cylinder, 49 lbs.
„ „ L.P. „ 12·1 lbs.
Stroke, 12 inches.

Revolutions per minute, 90.
Output, about 180 cubic feet per minute.
H.P. cylinder indicates 10·28 horse-power.
L.P. „ „ 10·10 „
Total power indicated 20·38 „

(H.P. = high pressure; L.P. = low pressure.)

The Ingersoll-Sergeant Drill Co.'s horizontal type of belt-driven air compressor has been extensively used in the Baku district, and has given satisfaction, and one or two horizontal direct-driven tandem steam compressors of the American Well Co. have also been tried, but the latter exhibit the chief defect of the cheaper American machinery, namely, softness of metal. The soft American cast-iron, of which many castings in the States are composed, certainly renders it possible to turn out clean machined work at a low price, but cheap machinery should be carefully avoided by purchasers, as it is doubtful economy to stint a few pounds when purchasing expensive plant. There is an opening for a good belt-driven vertical type of compound compressor of similar capacity to those mentioned, for there are indisputable advantages attaching to the vertical form.

Messrs. Hughes and Lancaster's horizontal, belt-driven, compound air compressor (Fig. 70A) has been introduced into the Baku oil fields for air-lift purposes, and has given very good results. This compressor is designed on a plan which has come into general favour during the last few years, chiefly on

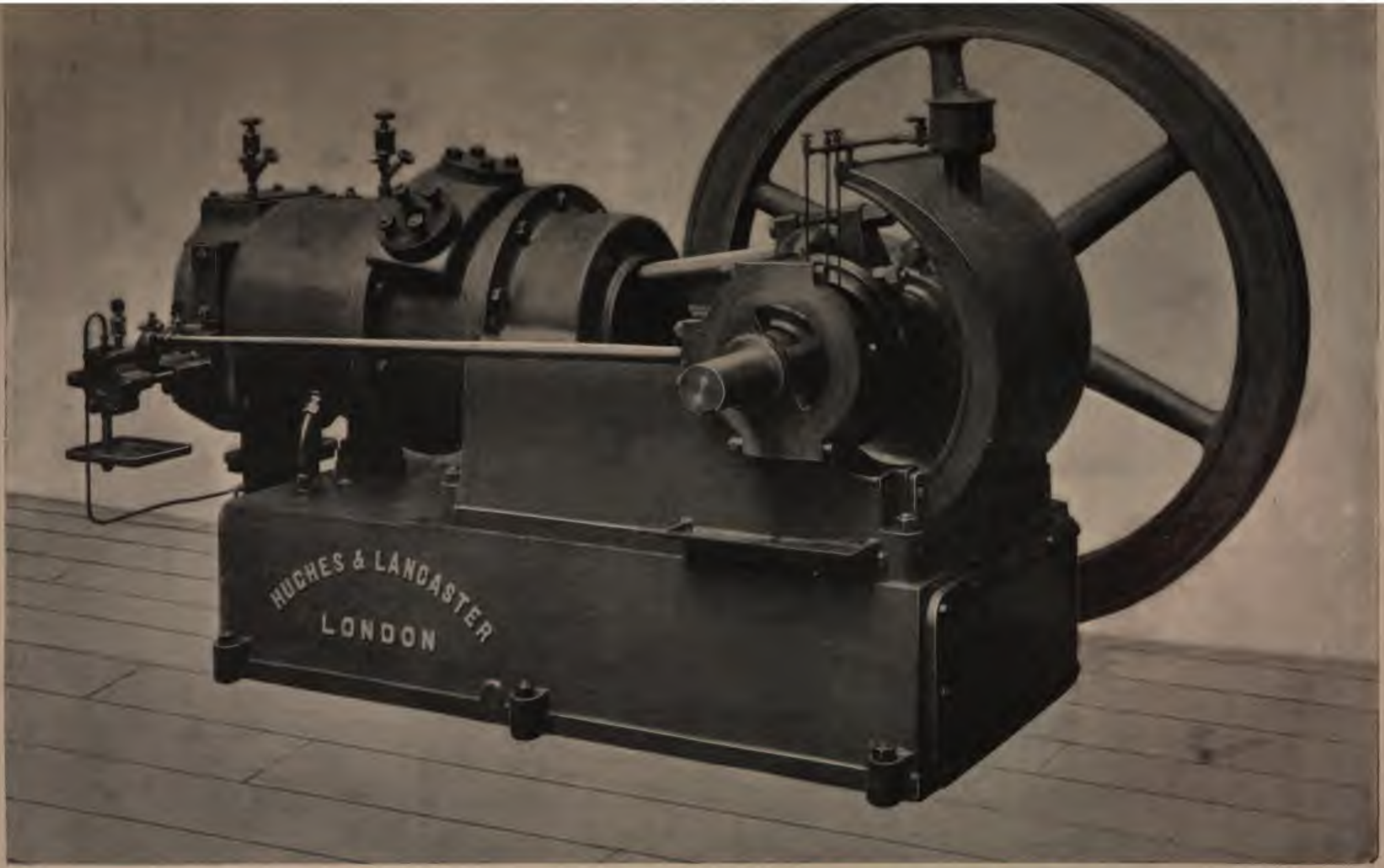

Fig. 70a.—Hughes and Lancaster's Air Compressor (as used in the Baku Oil Fields).

[*To face p.* 278.

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TILDEN FOUNDATIONS.

account of its compact nature. In this type of compressor the double compression is performed in a single cylinder, which has a diminished diameter at the forward end. The piston is of the plunger type, and the front portion is turned down so as to form an annular chamber between the piston and the cylinder; a second set of rings on the forward reduced part of the plunger preventing the escape of air past the piston. Air is drawn into the back end of the cylinder on the outstroke of the piston, and on the return this air passes through the intercooler, and then into the annular space round the trunk of the piston, where it is compressed on the next outstroke of the piston. Messrs. Alley and Maclellan also make a vertical form of the above design of compressor, which has been employed for air-lift purposes with great success.

The chief points to observe when ordering a compressor are—

(1) Facilities for cleaning, repairing, and renewing the suction and delivery valves.

(2) Attachment of automatic oiling fittings to all moving parts.

(3) Sufficient intercooling between the high- and low-pressure cylinders.

(4) Means for cleaning the water chambers surrounding the cylinders, etc.

(5) The supply of a complete set of renewals and spare parts.

There is a tendency on the part of manufacturers to stint the intercooling, which is more important in the Baku oil fields on account of the hot summers and the scarcity of cold water. The fly-wheels of compressors form a large proportion of the weight of the machine, and foreign makers should be asked to supply them without fly-wheels, and thus save much cost in freight and duty; but plans should be forwarded beforehand, so that the pulleys can be early ordered at local works.

The air supply should not be drawn from the engine-room, where the air is heated, but should be taken from as cool a place as possible, and where there will be no dust, for as air expands about 1 per cent. for each increase of 5° Fahr. in temperature, there is a direct loss of efficiency equal to this amount.

The atmosphere under normal conditions contains 4 grains of water per cubic foot, which amounts, in the case of a 300 cubic feet compressor, to about 1 lb. of water per hour, but under some states of the atmosphere this quantity is greatly increased, and during rains large amounts of moisture are drawn in with the air. The heat of compression keeps the water thus admitted in a gaseous condition, but on subsequent cooling in the delivery mains a large amount of this water is deposited, and, unless means are taken for its removal, it fills up the tubes. An after-cooler placed near the delivery of the compressor will cause a deposition of most of the water, but if no such provision is arranged, cocks must be fixed in the low-lying portions of the mains, which can be periodically opened to expel the accumulated water.

The following precautions should be observed in working compressors: The attendants should be warned not to admit paraffin or kerosene into the cylinders during work, to clean the valves, or a serious explosion may occur from the ignition of the volatilized gases, and so cause a fractured cylinder. Only lubricating oils of good quality, and those unaffected by a high temperature, should be permitted for oiling the cylinders, or the valves become quickly coated with a deposit of coke and their action retarded. If sea or oil-well water is employed for circulation purposes, frequent inspections of the water-jackets must be insisted upon to prevent accumulations of lime and salt from impeding the free movement of the water. Where possible, it is expedient to arrange for fresh or condensed water to be used for cooling, when the same water may be used again and again by erecting a small pump and arranging a circuit, the water being cooled by the introduction of a spray, and exposure to the air, or passage through a cold-water tank.

Methodical inspections or tests of the air mains should be enforced to ascertain that there are no escapes, for air leaks are not so readily discerned or their position located as steam, which expands into a cloud of condensed moisture whenever it comes into contact with the cool air. Many failures which have been attributed to other causes might be traced to undiscovered escapes of air, and many engineers have been baffled in their calculations by leaks, which have caused them to largely over-estimate the volume of air at their disposal.

TABLE XXIV.*

APPROXIMATE HORSE-POWERS REQUIRED TO COMPRESS 100 CUBIC FEET OF AIR PER MINUTE FROM THE ATMOSPHERE.

lbs. per sq. inch.	H.P. for one-stage compression.	lbs. per sq. inch.	H.P. for two-stage compression.	H.P. for four-stage compression.
10	3·60	60	11·70	10·80
15	5·03	80	13·70	12·50
20	6·28	100	15·40	14·20
25	7·42	200	21·20	18·75
30	8·47	300	24·50	21·80
35	9·42	400	27·70	24·00
40	10·30	500	29·75	25·90
45	11·14	600	31·70	27·50
50	11·90	700	33·50	28·90

* Extracted from *Compressed Air*.

CHAPTER X.

PECULIARITIES AND MANAGEMENT OF BAILING WELLS.

Attention to Bailing Wells.—Results of bailing from a newly completed well various and uncertain—Procedure at commencement of bailing—Discretion and attention necessary during first few months—Difficulties presented by water and sand—Trial bailings to determine relation of sand and water—Bottom bailing usually necessary in new wells to keep sand under control—Effect of gas in preventing production of plug—Removal of sand to prevent formation of hard plug—Procedure when sand forms a hard plug—Action of water in resisting and preventing admission of oil—Water to be kept under control—A certain minimum of water often to be left to prevent trouble with gas.

Bailing Intermittent Spouters.—Dangers and possibilities with periodically flowing wells—Indications of approaching flow, and procedure on these appearing—Amounts of oil yielded by continuous and intermittent fountains—Description of spectacle given by an intermittent fountain—Danger of losing bailer in sand after a fountain—Much time sometimes occupied in removing sand plug following a flow—Cause of this plug—A flow may often be induced at any time, but the proceeding seldom desirable—Occasional flow without warning; effect; precautions for this emergency—Periodical flow for a time, to recommence only after bailing—Intermittent wells at Grosny frequently left entirely alone—Further detrimental effects of sand plug.

Advantages accruing from Removal of Sand from Wells.—Removal of considerable quantities of sand producing a spongy reservoir which becomes filled by gravitation—Natural reservoirs of this kind must exist.

Effect of Gas on Production of Wells.—Action of dissolved gas in ejecting contents of rising bailer—Loss through this action liable to cause deceptive idea of value of well in early stages.

Speed of Bailing of Wells.—Difference of opinion as to best bailing speed—Amount of water an important factor—Modes of admission of water, and relation to speed of bailing—Experiment only can decide best speed for bailing when water is in the formation from which oil is being abstracted—Where no rise of plug nor increase of water, well may be bailed to full capacity—What is meant by "full capacity"—Reference to wells on the Balakhany-Saboontchy and on the Grosny oil fields—Damaged tubes and collapses chiefly due to landslips—Rates of bailing adopted by some large firms, and reasons thereof—Actual bailing velocity commonly employed at Baku—Modifications necessary in velocity and in machinery as wells get deeper.

Life of Oil Wells, and Causes of Loss of Bailing Wells.—Impossibility of furnishing data regarding abandoned and lost wells, with reasons for this—Circumstances leading to the loss of a well—These conditions considered in detail—Inlet of water in ways specified—What may be done to prolong well's life—Diagrams showing effect of failure to cement, and of failure to adopt water-excluding means on the part of neighbouring proprietors—A phenomenon observed by author just before admission of water from another source—Damaged and collapsed casing due to defect in casing, and occasionally to cementation of lower part only of a deep well—Landslips causing movements of casing—Occasional fracture of lower part of casing not resulting in diminished production—Drying up or exhaustion of source least frequent occurrence—Where found—To be expected in the next few years—Difficulty of forming an approximation of the life of a well—Average life in Russian districts—Length to be looked for with reasonable precautions—Some record wells.

Average Production of Wells in Oil Fields.—Average production of chief Baku oil companies—Average production of chief English oil companies.

CHAPTER X.

PECULIARITIES AND MANAGEMENT OF BAILING WELLS.

Attention to Bailing Wells.—Boring for oil has been classified with mining for minerals, and there is, no doubt, a great similarity, so far as luck is concerned, in getting those fountains and big producers which are at times a veritable gold-mine to the fortunate possessors. There are examples of two wells sunk side by side, within 40 or 50 feet of each other, where one has turned out an excellent producer whilst the other has scarcely shown a sign of oil; and there are numerous instances of fountains in close proximity to non-productive wells, conditions which an endeavour has been made to explain in Chapter II. of this work, which illustrate the futility of trying to estimate the quality of a source. Hundreds of wells, however, have been lost through bad construction and careless bailing and management; and the object of this chapter is partly to give a few hints on the treatment of bailing wells.

When a newly completed well is accepted from the boring master for active exploitation, and bailing proper is commenced, the results are various; for a large production of oil may immediately be obtained, a continuous or intermittent fountain start to flow, or strong gas may for a time cause bailing to be suspended. In other cases only water is bailed for weeks or months before it is finally overcome and replaced by oil; frequently sand rises in such huge quantities that an equal time is occupied in its removal by bailing.

In every oil well it is advisable to commence bailing very slowly from the bottom only, and so gradually direct the flow of oil into the bore-hole, but subsequently the speed may be increased and a proportion of top bailings be removed. Great judgment is needed in bailing new wells, and the engineer should always personally supervise trials, and never leave the duty to the discretion of a subordinate or junior.

Constant attention is required for the first few months to ascertain the size of bailer which gives the best results; but, of course, if there is no water or sand present, and the level of liquid is low, no great exercise of skill is demanded. When water is not perfectly excluded, oil wells may often be saved from ruin by judiciously bailing and gradually inducing the passage of gas and the flow of oil into the well, which will, by its own pressure when once admitted, exert sufficient force to prevent, at least for a time, the admission of water. The best course to pursue, when there is a collection of water in the bottom of the well which cannot be readily overcome, is sometimes to bail with a large bailer from the bottom, when the water may disappear and an immediate improvement will be observed; but in other cases the reverse happens, and if persisted in, such treatment will cause irretrievable damage to the well. In wells of the latter type a small bailer may keep the well moderately free from water; but the moment a larger bailer is used the water increases, the effect being probably due to the limited productive capacity of the source, where the water and oil pressures are practically in equilibrium.

A great improvement may be obtained in some wells by giving a proportion of top bailings at once, the entrance of the gas being thus facilitated, and the plug, if any, loosened, but such trials should only be made under the personal supervision of the engineer.

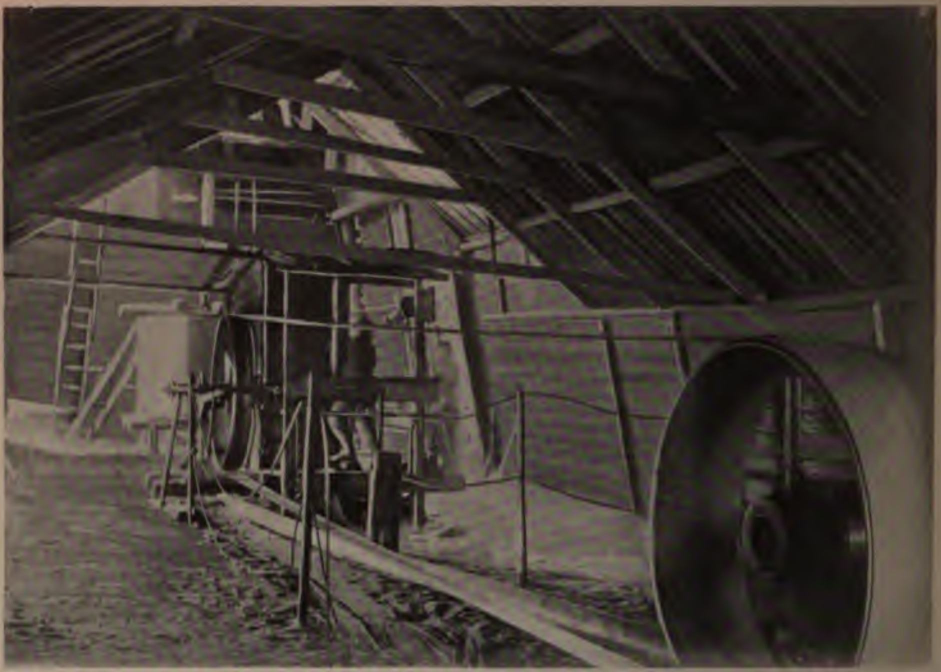

Fig. 71.—A Modern Bailing Well in Saboontchy, fitted with 16-feet Circumference Eisenschmidt Bailing Drum.

(Speed of bailing, 1500 feet per minute.)
(Well No. 31, plot 169, European Petroleum Co., Ltd.)

Rarely is an oil well entirely free from water, and owing to the fact that the specific gravity of the oil is less than that of water, the oil always separates, and finds its way to the surface, and unless kept in constant agitation by strong gas, the line of separation is distinctly marked; yet the presence of water in anything more than small quantities is often a serious obstacle to the free admission of oil. If bailing is continued for a few hours from the surface, or near to the surface of the oil in the well, it will be observed, on testing, that the water has increased in amount, and that the sand, which is only prevented from accumulating by bailing from the bottom, has risen in the tubes. It will also be found that the sand has formed a hard core—or what is locally termed a "plug" or "cork"—in the bottom of the casing, which may partially or entirely shut off the inlet of the oil, and which may afterwards prove very troublesome to clean out. Consequently, in new wells the exercise of considerable discretion is needed in the bailing, and frequent trial trips of the bailer must be made to discover to how great an extent the water and sand increase or diminish by variations in the proportion of top and bottom bailings. In nearly all new wells, bailing must be maintained solely from the bottom, with the one object of clearing away the tons, or even hundreds of tons of oil sand, which usually put in an appearance, and only after the sand ceases to rise may a proportion of the bailing be taken from the top, the amount of which can be gradually increased until both the plug and the water are kept stationary.

The liberation of gas causes at times such a violent agitation of the liquid in the well that from top bailings there is from 20 to 40 per cent. of water, and it is found that there is no difference in this proportion between top and bottom bailings; but in such cases the excessive gas, as a rule, prevents the formation of a plug, and 5 to 10 per cent. of sand will often be noticed in top bailings.

The formation of a hard plug must at all costs be prevented in wells, and in borings where there is constantly a small proportion of water at the bottom it may be advisable to cease bailing and adopt special measures for the removal of the sand. A plug may generally be reduced by transmitting a jumping motion to the bailer, *i.e.*, the bailer is raised a few feet from the bottom by the drum and allowed to fall rapidly by its own free weight, the effect being to impart a suction action to the sand, and a motion to the whole which results in sand and fluid entering the bucket. It is not uncommonly found that by the time the bailer has reached the surface, the enclosed sand has settled so solidly that it can only be removed by unscrewing the bailer valve, but sometimes it may be freed by lowering the bucket at a high velocity into the liquid, and then raising it again swiftly.

When the plug cannot be cleaned in the manner described, recourse is had to a heavy sharp-pointed instrument called a "pick," which is simply an iron rod provided with a steel point, and guides to keep it central, and sufficiently weighted to ensure its entering the sand when a succession of rises and falls is transmitted to it from the bailing drum. If the bailer then fails to clean the loosened plug, an American bucket, used alternately with the pick, must be tried.

A hard plug, composed of irregular particles of rock and fractured nodules, is very frequently met with, and whilst its presence does not seriously impede the free inlet of the oil, it is a source of considerable loss through the fragments finding their way on to the valve-seating of the bailer, and propping open the valve and so allowing the oil to escape. Bailer after bailer may in this way be raised empty, and in wells of this character it is necessary to clean the bore-hole out regularly with an American bucket.

An accumulation of water in an oil-producing well, whether from above or from the oil stratum itself, produces almost as effectual a resistance to the admission of oil as a sand plug, and although from 5 to 15 per cent. in a well with a big column of liquid is not usually detrimental, from 25 to 30 per cent. of well-defined water often closes the inlet of oil. Wells should be bailed in such a manner that the water is kept well under, if present; but it must be noted that the best producing wells often contain no less than from 5 to 10 per cent. of clearly defined water, and if this amount is reduced, the gas becomes so strong that the output is seriously diminished.

It should, perhaps, be explained that in ordinary oil wells there is a well-defined line of separation between the oil and the water; that is, a bailer lowered below a certain point will bring to the surface practically clear water—so clear that strangers will remark that there can be no oil in the well—whilst a bailer above this position will contain only oil, with perhaps a mere trace of water. In very gassy wells this line of separation is not formed, on account of the agitation to which the fluid is subjected. The position of the line of separation is ascertained by trial bailings taken from various depths, the exact distance being calculated from the number of revolutions made by the bailing drum during the bailer's ascent or descent.

Some wells, where the water could not be reduced by bottom bailing, have been bailed solely from the top at a rapid rate, with the result that a large oil production has been obtained, the composition of the removed liquid being, perhaps, no more than from 10 to 20 per cent. oil, but reaching a considerable quantity on account of the huge volume of fluid raised.

Bailing Intermittent Spouters.—Considerable care must be exercised in bailing wells which periodically flow, as there are numerous dangers and possibilities which do not attend ordinary bailing. If much sand is continually rising in the casing, as will probably be the case for many months, almost constant bailing from the bottom must be conducted to prevent its excessive collection and consequent choking of the well.

When a well is about to flow, indication is given generally by an increased evolution of gas, and a gentle but continued rise of the oil level, which warns the attendant at the bailing drum to use additional care. When the oil has risen to within 30 or 40 feet of the surface, one or two bailings are taken from the top of the liquid, when the lightening of the column and the suction action of the bailer combined assist the fluid to rise; but when the oil is within a few feet of the top, the brake of the drum must be applied and fixed, and the bailer left suspended in the derrick, whilst the operators retire out of the influence of the gas until the flow ceases.

The common periodical fountains play from 3 to 5 minutes, and discharge in that period a volume of oil equal to from 50 to 75 per cent. of the capacity of the tube from which they flow; but the well is so rapidly refilled that by the time the next bailer is lowered the normal level has been reached. Periodical spouters yield a much larger amount of oil within the definite period of flow than do continuous fountains, and are very much more beautiful to witness; indeed, to see a periodical fountain rising from a well of large diameter is a magnificent spectacle, and a sight not easily forgotten. An unbroken column of frothy, dark-brown oil, equal to the size of the well, rises very slowly and majestically above the tube, and falls in huge, graceful cascades on all sides, presenting, under the influence of a ray of sunlight, a beautiful appearance.

Higher and higher it creeps, its force steadily increasing, until the column plays vigorously to the summit of the derrick, where its further progress upwards is checked by the heavy cross-timbers surmounting the top. Then the pressure increases until a jet of mixed oil, sand, gas, and perhaps stones, is projected with a thunderous roar and enormous violence through the top of the derrick, accompanied by suffocating petroleum gases, which produce such a sensation of giddiness that, unless support is found against the side of the shed, the onlooker is likely to fall. After a few minutes of such behaviour a sudden subsidence and calm follows, leaving no evidence to the sight-seer of the recent violent eruption. A flow of this nature often yields 1000 poods a minute, and becomes so violent towards the end of the discharge as to dismantle the top fittings of the derrick, blow out the side framework, and even smash the massive corner-posts.

Great care must be taken when bailing intermittent fountains from the bottom, as the sand, which is kept in a very diffused and agitated condition, may suck in the bailer and lead to a long and difficult fishing operation, or even cause permanent injury to the well, for bailers lost under these circumstances cannot always be recovered. The first few bailers lowered after a fountain should be sunk with more than usual caution, as the bailer will sink freely into the loose sand which has congregated, and the sand held in suspension will also be precipitated upon it, if allowed to remain motionless for a few minutes.

Several hours, days, or even weeks may be employed in cleaning out the sand plug formed by one single flow, after which operation the gas increases, and the level of liquid rises until another fountain occurs; but the general type of intermittent spouter plays once or twice per hour or once every few hours. Some examples of the intermittent type of well give considerable trouble in their management, as each fountain is followed by a big plug taking weeks to clean; a wearisome and profitless business which may have to be repeated for many months, during which time practically no production is obtained. The cause can usually be traced to the presence of a more than permissible quantity of water, which causes the oil sand to settle like cement after each fountain, and such wells have frequently to be deepened or cemented before any use can be made of them. Oil sands free from contamination with water can be bailed up in the ordinary bailer with the greatest ease, and it is no uncommon sight to see sand saturated with oil being raised in the bailers with as much freedom as oil; but the presence of even a small percentage of water entirely prevents this.

In many periodical spouters a fountain can be induced at almost any time by taking a few bailers of oil from the surface of the liquid; but this practice is inadvisable, except in isolated cases, for such treatment usually encourages the formation of a hard plug which may take a long time to clear, although in some instances the reverse is the case.

Fountains occasionally appear without any previous warning of their approach, and if the bailer happens to be near the top, or suspended about midway in the liquid, it is shot violently from the bore-hole and smashed against the derrick-top. If the bailer is near the middle of the well at the moment of eruption, several hundred feet of wire rope in addition to the bailer are flung up, the former in a tangled and knotted state which renders it practically useless for further work. If the bailer is near to the bottom when an unexpected flow commences, it lies below the influence of the more rapidly ascending oil, and escapes damage; but the attendant must on no account leave the bailing drum, and must keep the bailer gently in motion the whole time, raising it rapidly to the surface immediately the spouting ceases. Failure to follow this instruction will cause the bailer to be buried in the sand settling rapidly from the agitated liquid above.

In wells of small diameter, where the size of bailer closely approximates to that of the lining tubes, the gas is so strong at times that bailers cannot be made to sink in the well for a time, and in most cases the above-mentioned accident of ejected bailers is of frequent occurrence in wells that periodically disclose this peculiarity. Periodical fountains will occasionally spout at intervals for days without the assistance of bailing; but ultimately the gas is diverted or excluded by the accumulation of a plug, and bailing must be recommenced to induce a flow. In Grosny, wells are frequently left entirely alone, in which case they spout at intervals when the gas has collected sufficiently to excite a natural flow; but in this field no sand plug rises to exclude the free admission of gas and oil.

Advantages accruing from Removal of Sand from Wells.—The effect of a plug in wells is detrimental in other ways than those mentioned, for as a result of the diminished pressure in the tubes, the inlet of water is encouraged through faulty rivet-holes or badly caulked joints where it is not perfectly shut off; the gas is often diverted between the casings, and water sources, previously excluded, are opened. Further, the accumulation of plug prevents the formation of a reservoir, or at least an area of less density, into which the oil may gravitate and collect ready for removal.

There is probably more in the last suggestion than is usually suspected, for rarely is an exceptional producer obtained which does not give at first enormous quantities of sand. The oil sand offers a certain resistance to the movement of the oil, and the effect of bailing out considerable quantities is to create an area around the well, which, although not a cavity, is a region of reduced density, towards which the oil flows by gravitation after the initial gas pressure has expended itself. That such natural reservoirs are formed in the Baku territories, from which the bailers draw their supply, is indicated when boring a new well near to the site of an old one; for at the depth formerly bailed, the sand is very loose, and sometimes gives much trouble to pass through, whilst the same sand, at a greater distance from the abandoned well, is much more compact.

Effect of Gas on Production of Well.—A new well which has reached a very prolific stratum, but from which the oil does not flow naturally, may for many weeks or several months yield nothing but a merely nominal output on account of strong gas. The bailers, when deeply immersed in the liquid, are filled with oil supersaturated with gas under a high pressure, which, during the bailers' forced ascent through the liquid, cannot escape; but immediately they are raised from the oil, the dissolved gas, no longer under any resisting pressure, is evolved with such rapidity that the greater portion of the bailers' contents is also ejected, and the bailers reach the surface nearly empty. The action is similar to that on opening a bottle of aërated water, where the dissolved carbonic

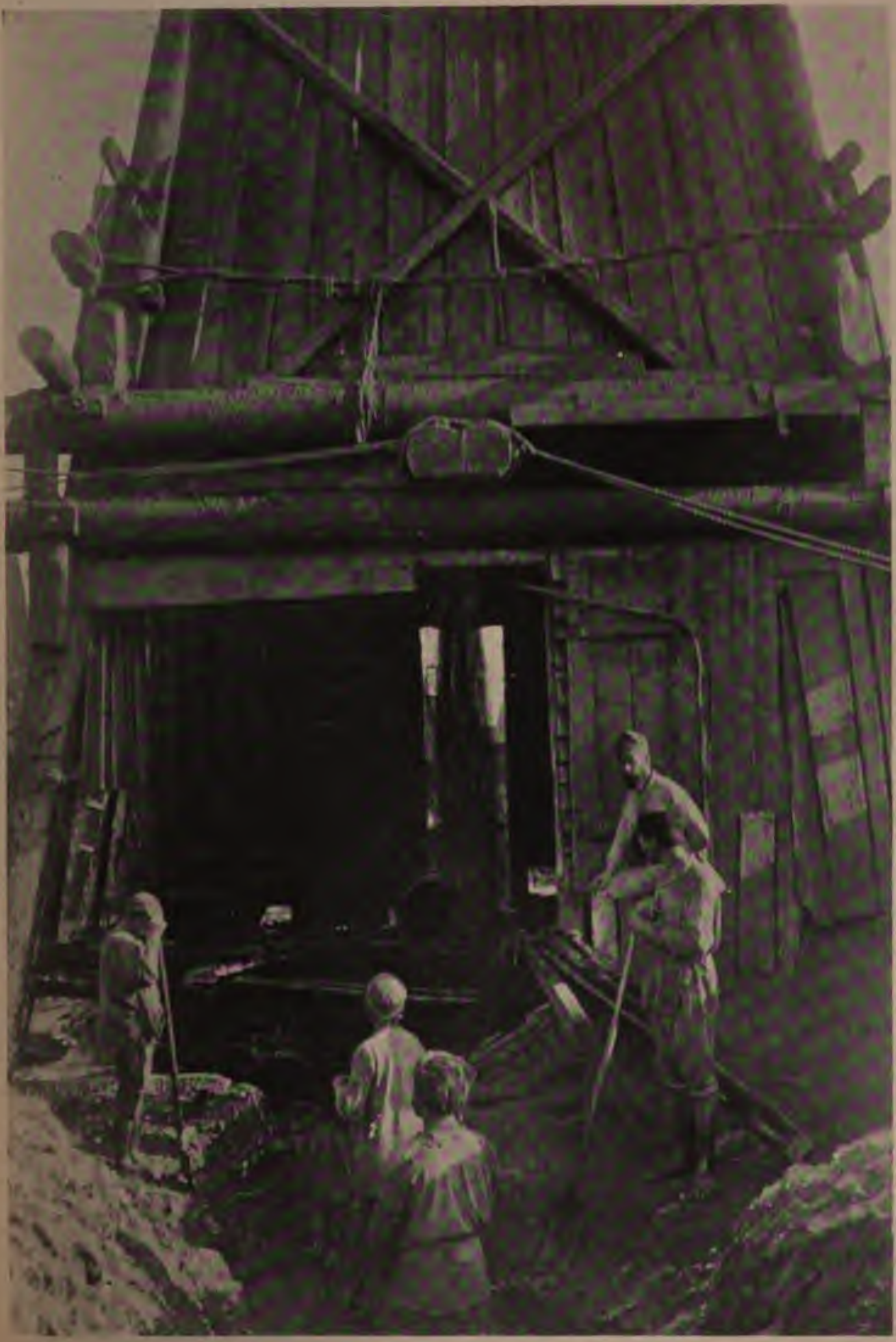

Fig. 72.—A Saboontchy Periodical Spouter, showing usual Arrangement of Derrick and Facilities for clearing away Ejected Sand.

acid gas under pressure, unless care is used to allow it to escape slowly, may discharge half the contents of the bottle in its rush through the narrow neck.

If the bailing speed is high, and the level of the liquid near to the surface, the bailer is often raised still overflowing, and may continue to expel its contents for half to three-quarters of a minute, if left suspended in the derrick, producing a very beautiful effect, but preventing any one from approaching. Bailers raised from gaseous wells often do not contain 10 per cent. of their actual capacity of oil on reaching the surface. The shape of the bailer conduces to exaggerate this effect, the confined neck assisting in the formation of such a miniature fountain by restricting the exit.

The ordinary daily reports of the production of new wells are very deceptive, and give a very wrong impression of the actual worth of the boring; in fact, those unacquainted with the peculiarities and characteristics of oil wells might form a very unfavourable opinion of an excellent well. Months of patient bailing are often needed before a well, devoid of all water, can be brought to a highly productive state, on account of the excessive gas which renders bailing almost unproductive; but a well yielding only 2000 poods a day may give eventually as much as 8000 to 10,000 poods after the escape of the excess of gas.

Speed of bailing of Wells.—Difference of opinion exists as to the most advantageous speed for bailing wells, and many Russian engineers strongly advocate slow bailing and condemn rapid removal of oil; but the relation that water bears to the yield seems to be very imperfectly understood, and views are constantly being expressed and articles written pointing out that heavy bailing draws in water and leads to the early loss of the well. Formerly, engineers had cause to fear flooded wells and collapsed casing if fast bailing was persisted in, as the lining tubes of the wells were of inferior construction, and the cementing process, with its increased strength, had not then reached the state of perfection it has to-day; but now there is no reason to fear fast bailing from this cause if the well is properly completed, and engineers have confidence in their own work.

Water finds admission into a well in two ways—either from a water source situated above the oil stratum which has not been shut off securely, or from the formation from which the oil is being abstracted. In the former case the well is a badly constructed one, and the inlet of water is due to defective work—a fault which can neither be avoided nor repaired, perhaps, but still it is a serious defect, and must be acknowledged as such. In the latter case the water may have been present originally in the oil source, although this is very doubtful, or it has run into the oil stratum before the overhead water was excluded, or it is derived from other faultily completed wells in the vicinity, which admit a constant stream of water into the oil formation and dilute the source. In the first case there is a formidable danger from overbailing, and a heavy column of oil may be the means of preserving such a bore-hole from total failure, as this head alone prevents the well from being flooded. In the second condition it is impossible to foretell what variety of bailing will give the best results, and experiment alone can decide the point.

The author has had experience with a number of wells of the latter type, and whereas, in some holes, fast bailing with a large bailer has been followed by the disappearance of the water and a greatly increased output, in other examples the results have been best by bailing slowly with a small bailer; but nearly always the well's productive career is doomed, and it will sooner or later come to an abrupt end.

Experience has proved that the level of oil in wells will fall ultimately, whether bailing is conducted quickly or slowly, and unless there are special circumstances, *and neither the plug rises nor the water increases*, there is no reason why the well should not be bailed to its fullest capacity, irrespective of all fluctuations of level. By bailing a well to its fullest capacity, it must not necessarily be inferred that the use of the largest bailer which will pass freely in the casing, or the removal of a large proportion of oil from the top, is meant; but it implies the employment of a bailer which will be found to raise the greatest quantity of liquid, for it will often be found that a reduced production follows the use of the larger bailer or frequent top bailings on account of the gas excited by the suction action.

In practice the longest possible bailer which can be manipulated with ease is ordered, as the diameter may be proportionately decreased to obtain the same capacity, and the suction action and excitement of gas is thereby diminished.

Numerous properties and even districts could be mentioned on the Balakhany-Saboontchy plateau where formerly the oil level stood near to the surface, and where, doubtless, fast bailing was condemned, as it would cause lowering of level and consequently flooding by water; yet on the same plots to-day, almost drained of oil, and the gas reduced to a mere fraction of its original power, the oil level standing only 20 to 30 feet from the bottom when the water is totally excluded, the wells neither collapse from external water pressure nor are flooded. In the Grosny oil fields, a large proportion of the wells are bailed quite dry every day, many of which were originally fountains, and all of which have passed through exceptionally heavy water sources.

Damaged tubes and collapses will occur anywhere, especially in congested areas, notwithstanding all the engineering skill originally expended on them; but these are chiefly due to landslips and not to external water pressure, as is indicated by the large proportion of accidents not being followed by an influx of water.

Some of the large firms make a practice of bailing at a slow rate, or at least of regulating their speed by the fluctuations of level of the oil, *i.e.*, the velocity is diminished or the size of bailer is reduced on a fall of oil level, and increased to within certain limits with a rise—a system to be recommended in very large companies for two reasons: firstly, such syndicates prefer a steady, continuous bailing production to a constantly fluctuating one, as their business arrangements are more conveniently suited, and permanence of output is better assured; secondly, they cannot always rely upon the vigilance and discretion of the many sub-managers, who would, without some definite rule, direct the bailing more or less upon their own responsibility. It is a good principle, as little is left in the hands of subordinates; but small firms, and those with limited funds available for exploitation, cannot usually afford to behave in this manner, and aim at procuring the greatest quantity of oil in the shortest period. One large Baku firm never uses bailers exceeding 10 inches in diameter.

Many of the Baku companies arrange their machinery for bailing at a velocity of about 1000 feet per minute; but although this is often exceeded, and even doubled in some instances, it represents a fair average speed in wells of moderate diameter. As the wells get deeper and deeper (for many are now approaching 2000 feet), unless other means are devised for raising the oil, a considerable modification of the bailing speed will be necessary, and in a few years engines of greater power and bailing drums of different construction will be needed, as a bailing speed of 2000 feet per minute may become general.

Fig. 73 graphically illustrates many of the peculiarities of oil wells in the Baku oil fields. The particular wells chosen were representative examples of their class, and no reference to the production was made prior to the preparation of the figure, so that they are not picked wells chosen for the similarity of their features; nevertheless, no one can help observing the regularity of the changes of production in both examples of the same type. The four wells have been figured from the commencement of bailing, but the curves are made to start from the same line in order to compare the peculiarities at equivalent periods of their exploitation, but in reality many months, and even a year, intervened between the times when the wells were completed and bailing commenced. Curves A and B represent the fluctuations of output from two wells completed in a hard rock formation, that yielded, in the case of A, a little sand, but in the example B, no sand; and curves C and D represent the changes of yield in two wells completed in a loose-flowing oil sand. The four curves show the following features, all of which have been enumerated and described in this chapter and in Chapter II.:—

Curves A and B illustrate—

(*a*) The fact that the maximum production obtained from an oil well sunk in hard rock is at the commencement of bailing.

(*b*) That the fall of production is rapid.

(*c*) The striking resemblance in the fall of output.

(*d*) The regular yield when the production has reached a certain point; an amount which, in reality, represents the maximum yield of the rock.

Curves C and D illustrate—

(*a*) That the production is small at first, and months pass before the maximum output of the well is secured. This is due to much sand, strong gas, and, in the case of curve D, to a little water at first.

(*b*) The great fluctuations of output at comparatively regular intervals, due to probable breaking down of barriers that impeded the flow of oil from another part of the sand when one section had become partially drained.

(*c*) The steady decline of production after the maximum output had been attained.

The author attached considerable importance to the methodical preparation of diagrams similar to the appended; for after some experience, he found that by their aid he could very approximately foretell, from the initial peculiarities that a well disclosed, what the production of a well would be at certain periods, provided no accident occurred to the tubes, and water did not break in.

Life of Oil Wells, and Causes of Loss of Bailing Wells.—It is quite impossible to prepare any reliable data which would furnish even approximately

the percentage of wells which are abandoned through exhaustion of oil, or lost through various reasons, because (*a*) it is not always possible to ascertain with certainty what the destructive agency is; (*b*) it may be due to the combined action of several forces; (*c*) no official statistics have been prepared, or particulars demanded; (*d*) the percentage from different causes varies in each district, and is affected, as will be explained, by the activity of the local exploitation, the manner in which the work is conducted, and the quality of the casing employed.

The circumstances which lead to the loss of a well are—

(1) Inlet of water and flooding of well.

(2) Damaged and collapsed casing.

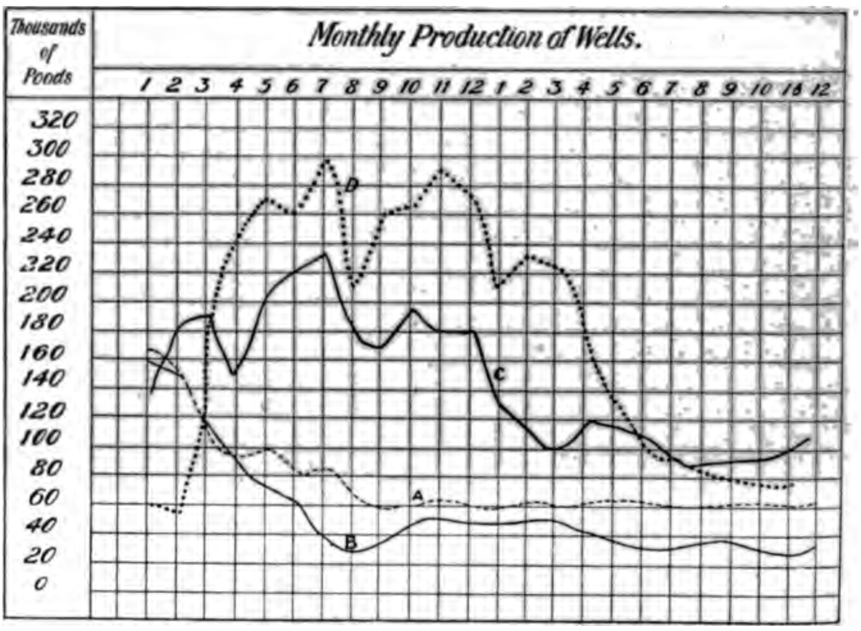

Fig. 73.—Showing Principal Features of the Yield of Oil Wells in the Baku Region.
Curves A and B represent production of wells completed in rocky strata.
Curves C and D represent production of wells completed in loose oil sand.

(3) Landslips and falls of strata.

(4) Drying up or exhaustion of oil source.

(1) *Inlet of Water.*—By far the largest number of wells are lost through admission of water into the bore-hole, either through imperfect exclusion of water from overhead strata in consequence of badly riveted or damaged casing; or from entrance of water into the oil source from neighbouring, carelessly executed wells.

If water begins to show itself in a producing well in more than usual quantities, bailing must be conducted largely or entirely from the bottom, to prevent the accumulation of an amount which will resist the admission of oil or totally exclude it. For a time success may reward the efforts made to check the increase of water; but if the well is uncemented, its fate is usually sealed, and its life can only be prolonged for a while by skilful bailing.

The diagrams (Fig. 74) are prepared from the records of three wells in the Saboontchy field, and demonstrate graphically some of the features characterizing oil wells and the serious effect of water admission through failure to cement.

In Example A (Fig. 74) the rapid fall of production is very marked, and the vexation of the proprietors was further intensified by the really magnificent results obtained from a neighbour's well carried down to the same depth, and not more than twenty paces away, but successfully cemented. This particular well cost fully £8000 to complete, and would have yielded, if properly cemented, from 1,000,000 to 2,000,000 poods a year, instead of which it was abandoned after giving only 1,000,000 poods, whilst the neighbouring well, within 50 feet and in the same sand, has produced about 6,000,000 poods in three years. Diagram A (Fig. 74) is interesting, as it shows the effect of compressed air in a well where the water could not be overcome by bailing. The continuation of the curve after the interval represents the results of the air lift.

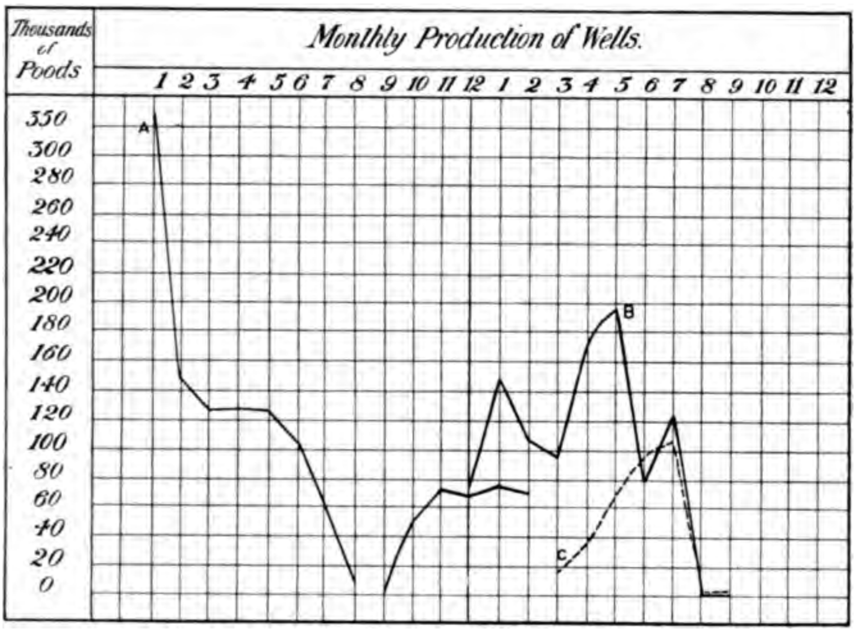

Fig. 74.—Showing Effect of Water Admission on Production of Oil Wells.

Close to the last-named bore-hole was another well which had not been cemented, and which was consequently taken possession of by water after yielding a million poods in a few months, but which would certainly, with proper cementation, have continued to produce handsomely for a long time. Both of the wells referred to above were located on one of the most prolific properties in the Saboontchy field, and the extent of the direct loss sustained by such wretched work cannot be estimated at less than £30,000 in output alone.

Another cause of loss of wells in congested districts is due to the carelessness or refusal of one proprietor to adopt measures for the exclusion of water from his own wells, and the consequent extension of water, so admitted into the oil formation, to adjacent wells. This is a very common occurrence in the Russian oil fields, and until legislation is introduced enforcing the shutting off of water in all wells—although it must be admitted that this is a delicate subject to legislate upon, and open to grave objections—there will always be a few old-fashioned owners who will never go to the expense of such operations. The curves B and C in the diagram (Fig. 74) represent the effect of water admitted by one uncemented well on two fair producers out of four, which on the same day all turned to water. The water broke in without any warning, entirely displacing the oil, and the four wells never yielded any more oil at this depth.

The two diagrams also illustrate a feature which the author has many times observed in wells which have been flooded by water admitted from an outside source, namely, a decided increase of yield prior to the water's actual admission, the improvement being most noticeable a day or two before the appearance of the water. This seems to be due to the driving of the oil before the water wave or influx, with the result that the oil is virtually forced towards the point of abstraction. The change to water is not gradual, but almost instantaneous in cases where this peculiarity has been noticed; and this also confirms the view that the oil is impelled forwards by the movement of a large volume of water.

The manner in which good wells are spoiled by one faulty neighbouring one is seen on reference to Fig. 76.

(2) *Damaged and Collapsed Casing.*—Wells are constantly being lost through damaged and collapsed lining tubes, arising from natural weakness, and not from extraneous agencies, such as employment of inferior quality of tubes, badly performed riveting, etc. If the casing is constructed of very soft iron, with only one row of rivets, the external water, earth, or gas pressure often leads to a collapse.

Badly manufactured and riveted casing is instrumental in causing collapses in two ways: firstly, it provides weak spots where the tubes may break or separate; and, secondly, it allows salt water, sand, and perhaps gas, to discharge into the well, and these, acting singly or in conjunction, rapidly enlarge a leaky point or rivet into a large tear. A carelessly caulked joint, which admits but a few drops of water at first, in the presence of sand and gas, or even water and sand at a high pressure, will, in the space of a few months, be enlarged to a hole of sufficient dimensions to admit the hand, and a single rivet-hole, from which a rivet has fallen, will be eroded to almost an equal extent. When the erosion has extended, the tubes can no longer withstand the external pressure imposed upon them, and collapse is inevitable.

An accident of greater rarity is caused in some low-level wells through the total exclusion of the water by cementation in the lower sections of the well, the head of water behind the casing leading subsequently to a collapse; but this danger can always be averted by cementing the well completely to the surface, or filling the annular space behind the casing with other impervious matter.

(3) *Landslips.*—In new districts, where the strata lie untouched, landslips

are not frequent; but on extensively exploited areas, where enormous volumes of sand have been removed by bailing or discharged by fountains, they are a constant source of annoyance and discouragement to the engineer.

The effect of a landslip may be to carry a few lengths of casing entirely away, and lead to a fall of impermeable ground which entirely excludes the inlet of oil; or it may drive the tubes to one side, and give them a deflection, which, although not causing a complete fracture, seriously obstructs or entirely prevents bailing. The damage to the tubes may be slight, but sufficient to admit water, which flows down and floods the well; or a total collapse may result from the landslip, and shut off the oil. In some cases the damaged casing does not prevent the free admission of oil, and the well continues to produce almost as much as previously by bailing above the fractured locality; indeed, occasionally such a collapse is followed by an influx of oil from an upper source, which more than compensates for the lost one.

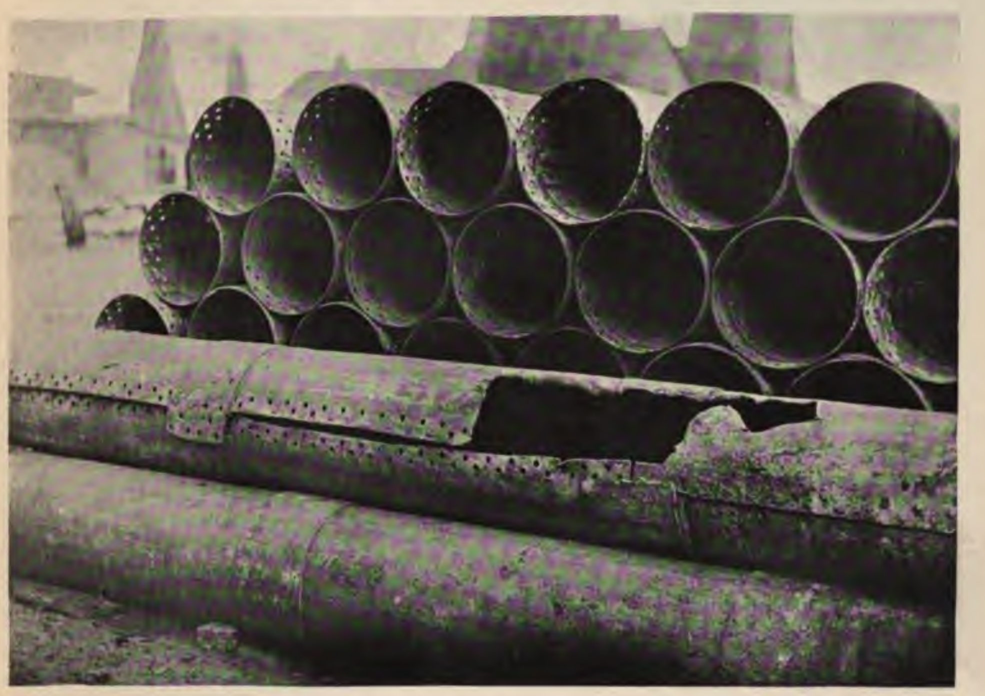

Fig. 75.—A Damaged Piece of 18-inch Casing removed from a Saboontchy Oil Well.

One of the most common forms of accident is the deflection of the lower portion of the well casing, which gradually moves more and more, by almost imperceptible stages, out of vertical, until no bailer will pass beyond the point where the curvature commences. The steady manner in which the curve extends points to the slow movement of the mass of sand in which the tubes are inserted, no doubt in the direction from which most oil and sand are being abstracted.

Fig. 76 roughly shows how the casing becomes bent or fractured, X being the direction in which many wells are supposed to be drawing their supply of oil from a single prolific stratum.

Where there is a strong gas pressure and a high level of liquid, a fracture of the lower lengths of casing is not always accompanied by any fall of production; and mention is made elsewhere of wells which have suffered collapse or fracture several times in succession, to the benefit of the well under some circumstances.

Where the lining tubes are deeply immersed in an oil sand, they are very sensitive to slight movements or falls of strata, and are frequently forced out of vertical without sustaining fracture; but by the same action they are sometimes pushed back again into their vertical position, after lying weeks, and even months, out of line. The author has observed this curious effect in no less than three separate bore-holes.

(4) *Drying-up or Exhaustion of Source.*—This is the least frequent cause of the abandonment or loss of wells, and it is only experienced, as yet, in a few parts of the Saboontchy and Romany fields, to a larger extent in the Balakhany district, and frequently at Grosny, but it is practically unknown as yet in the Bibi-Eibat oil territory, where wells are only lost through flooding by water or collapsed casing. During the next few years exhaustion of wells will largely increase, especially on the central part of the Balakhany-Saboontchy plateau, for the beds on the side of the anticline are now being actively exploited in the form of a semicircle, and there is no doubt that the oil will gravitate to those parts when the sands have been loosened and the gas has found relief.

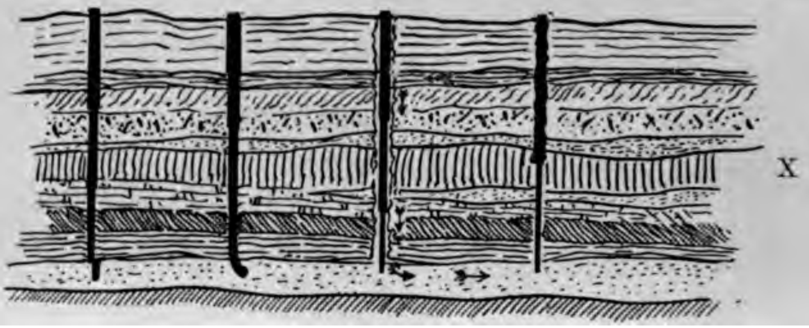

Fig. 76.—Sketch showing how Well Casing can be Fractured, and how Water can be admitted to the Oil Stratum from an Upper Water Source.

It will be seen from the foregoing remarks how difficult it is, under existing conditions, to form even an approximate estimate of the life of a well; but if an average were taken of all wells in the Apsheron Peninsula, it would probably not exceed one year, owing to the frequence of collapses, etc. If every endeavour is made to avert danger by supplying only tubes of good quality, with the addition of a protective column, by carefully cementing and excluding all water, by bailing judiciously and preventing the formation of a plug, the life of a well should not be less than 5 years in any but very actively exploited regions, and it might extend to 7 or 10 years in rich territory. Unfortunately, in 90 per cent. of the wells an unforeseen landslip or accident, for which no one is responsible, occurs, and prevents these results from being attained; but there are isolated wells which have been bailed night and day for 10 years without cessation, as, for instance, one of Messrs. Nobels' on Plot 178 Saboontchy, which has been bailed without intermission for 12 years, and has yielded in that period no less than 24,000,000 poods, or 96,000,000 gallons, of oil.

Average Production of Wells in Oil Fields.—The average production of oil from wells is low, even when fountains are taken into consideration, for in 1901 and 1902 the quantities were—

	1901.	1902.	
Balakhany	400	390	poods per day.
Saboontchy	1000	974	„ „
Romany	1600	1750	„ „
Bibi-Eibat	2500	2580	„ „

The average production per well per day for the five largest Baku companies was, in 1901 and 1902—

	1901.	1902.	
(1) Nobel Bros.	1600	1300	poods per well per day.
(2) Mantasheff and Co.	1200	1050	„ „ „
(3) Baku Oil Co.	850	540	„ „ „
(4) Caspian and Black Sea Co.	1400	1210	„ „ „
(5) Caspian Co.	2300	1760	„ „ „

The English companies of importance had the following averages:—

	1901.	1902.	
(1) Baku Russian Oil Co.	1100	1050	poods per well per day.
(2) European Petroleum Co.	1300	1400	„ „ „
(3) Russian Petroleum and Liquid Fuel Co.	3000	2500	„ „ „
(4) Schibaieff Petroleum Co.	1400	1650	„ „ „

NOTE TO CHAPTER X.

When overhead water is unexcluded, or only partially excluded from an oil well, there is a constant conflict in progress between the oil and the water for supremacy in the bore-hole. So long as the gas pressure, exhibited by the level of oil, is greater than the pressure due to the head of water, the well is not likely to suffer severely from failure to exclude water; but if the oil-level is reduced, by the withdrawal of liquid, to a point where the weight of the column of oil is less than the weight of water, the latter rushes in.

In a well where water is unexcluded, the column of oil must stand at least 15 per cent. higher (on account of the difference of specific gravity) than the normal level of the water, in order to prevent the admission of large volumes of water into the bore-hole. If this oil-level is lowered, water enters; and if oil is removed from the top of the liquid, water soon displaces all the oil in the well. The amount of water which can obtain admission to a well, when unchecked, is almost unlimited; and if an air lift is installed, or bottom bailing is persisted in, when the level of liquid has fallen beyond this point of equilibrium, practically nothing but water will be obtained. If the rate of removal of liquid is diminished, and the gas pressure is sufficient to maintain a higher head of oil than the water, a fair production of oil can sometimes be secured. In many wells the upper water is partially excluded, or it finds an entry through faulty casings in quantities that cannot be overcome by bailing on account of the small diameter of the well, and in such wells an immediate improvement results from the application of the air lift.

The air lift is often installed in an oil well which has turned entirely to water, and in such cases, no appreciable quantity of oil is obtained, until the entire column of water is replaced by oil. As soon as water is removed faster than it enters, oil commences to collect in the well, but, on account of the specific gravity, it rises to the surface of the water. The area of the air-lift suction pipe is so small compared with the area of the well (in the case of a 2½-inch main in a 14-inch well, the proportion is about 1 : 30) that practically no oil is yielded by the air lift until the whole of the water has been displaced by oil, and the entire column of liquid, to the point of admission to the strainer, is composed of oil. It will thus be seen that liquid removed from a point above the strainer will be, in nearly all cases, composed of oil only. The author has tested this many times by lowering small bailers; but even where these conditions prevailed, he has seen several wells where only water has been yielded by the air lift. This was doubtless due to a higher water pressure than oil pressure; for when, as occasionally happened, the inlet of water was temporarily arrested by a caving of sand around the casings, a fall of level of liquid in the well was at once indicated by a fall of pressure on the gauge, and for a few minutes (5 to 15) almost pure oil was discharged. Suddenly the water would break in again, the pressure would increase, indicating a rise of level, and water would again be ejected.

CHAPTER XI.

FOUNTAINS.

Fountains.—General description and mode of production—Baku the home of fountains—First fountains struck at Baku—Disastrous effects of some gigantic fountains by flooding—Fountains the only kind of well bored for, after probability of finding them was demonstrated—Effect of this wasteful method of exploitation—Fountains now only looked for in newer districts, and not always welcomed—Figures showing total increase of oil production in recent years, but decrease of fountain oil—Various ways in which a fountain is preluded—Provisions to be made for an expected fountain—Immediate measures on a well beginning to spout—Preparation of derrick by introduction of "fountain block"—Dangerous nature of work at a fountain—Effect of gas on workmen—Measures primitive compared with those of America, but conditions different, and American fountains insignificant by comparison—Fountains at first shut down by gate-valves, but the plan afterwards found to divert the oil to other wells—Other objections to control of spouting wells—Permanent damage to wells done by fountains on the borders of the Romany Lake—Sand-blast action of fountain on casing—Description of spectacle presented by fountain—Fountains unaccompanied by sand—Largest flow in one day from a single well—Some account of a few remarkable fountains, and the damage they caused.

CHAPTER XI.

FOUNTAINS.

Fountains.—Fountains, gushers, or flowing wells, met with in nearly all the oil fields of the world, owe their origin to the escape of gas dissolved in the petroleum under great pressure, which, on finding relief by means of a bore-hole tapping the source, rushes upwards, carrying oil, sand, and stones in its movement, and ejecting them with considerable force from the tube. When the initial violence of the gas has expended itself, and a cavity or large area of low density is formed at the bottom of the tube, the action resolves itself into simple aëration of the petroleum; in fact, being identical with the effect obtained on opening a narrow-necked bottle of aërated water, when the evolved gas carries in its exit a large proportion of the contents—the tube representing the neck of the bottle, and the stratum or oil reservoir beneath being equivalent to the body of the bottle. Baku is the home of fountains, and on the Apsheron Peninsula spouters have been witnessed which throw into insignificance any before recorded in any part of the world, their magnitude not only arousing local interest, but exciting the wonder and curiosity of scientists in every country where the reports have found circulation.

The first Baku fountain was struck by the Khalify Company, on the Balakhany Plateau, in the year 1873, and although it was a small flow compared with many subsequent spouters, it had the effect of causing the price of oil, which then stood at 45 copecks per pood, to fall to 5 copecks, and of revolutionizing the petroleum industry. A few years later the famous Droojba fountain was struck at a depth of 574 feet, by a small Armenian company trading in Balakhany, and this yielded such stupendous volumes of oil that all the surrounding district was submerged in oil to a great depth, causing intense local excitement. The well is estimated to have yielded no less than 400,000 poods of oil a day for a time, and about 30,000,000 poods (120 million gallons) altogether before the flow ceased, and the unhappy proprietors, who were quite unprepared for such an event, were inundated with demands for compensation from neighbours who had their ground buried in oil and sand, and were obliged to go into liquidation.

About the year 1883, many fountains were struck that yielded from 5,000,000 to 15,000,000 poods of oil, which entailed no labour beyond its removal, and whilst in some cases lakes of oil, which had collected in natural depressions on the land, were disposed of by burning, in other cases the owners took to flight to escape the heavy demands for compensation that came pouring in. About this period the price of crude oil did not exceed a fraction of a copeck per pood, and millions of poods of fountain oil were sold at a merely nominal figure to secure its removal; but often the surplus oil that could not be stored was allowed to run into the Romany Lake, where it accumulated to such a degree that it became a nuisance to the district, and was fired to clear it away. The wanton waste of petroleum about this period caused much indignation when the facts were brought to light in the press, for it is not improbable that for several years as much oil was deliberately thrown away or destroyed annually as the entire output of the whole of the American oil wells.

Several plots of land leased by the Russian Government to individuals in Bibi-Eibat had been worked for oil for years by means of hand-dug wells, but the value of this oil field was not appreciated until 1886, when Tagieff struck, at a depth of 700 feet, a fountain which totally eclipsed in proportions all that had been met with on the Balakhany Plateau. The gas and oil burst forth with furious impetuosity when the oil stratum was tapped, and old residents describe this fountain as wonderful to witness, for the owners were taken quite unawares, and had made preparations neither for restricting the flow nor for storing the output, with the result that at the first eruption the derrick was blown away, and a column of oil, gas, and sand rose vertically to a height of several hundred feet, a prey to the mercy of the winds. Not only was the village of Baieloff deluged with the oil, but the houses and streets in Baku, three miles away, were disfigured with dark oil, and covered with a fine deposit of sand, and the whole of the Bibi-Eibat valley was rendered almost impassable. The oil, which was being discharged at the rate of about 700,000 poods a day, equal to 2,800,000 gallons, soon filled the temporary storage improvised in the vicinity, broke down the earthen embankments of which it was composed, and flowed in an unchecked stream to the Caspian Sea, where it was lost for ever, and very little of the 5 million poods of oil the well is reported to have yielded without cessation was preserved.

In the following year, 1884, a second gigantic fountain was struck by Zubaloff, on a property not many yards from Tagieff's plot, nearly rivalling the former in proportions, and although provision had been made for large storage, the retaining walls broke down, and the oil flowed into the Caspian Sea. These two huge spouters, which advertised the value of the Bibi-Eibat territory, and dispelled all doubts from the minds of oil producers as to the richness of the ground, were the pioneers of extensive exploitation on this oil field, situated within a short walk of Baku itself.

The low price of oil prevailing about this period was prevented from rising by the repeated striking of prodigious producers, notwithstanding the rapidly increasing demand, and proprietors were led to bore for fountains only, no well being stopped in oil ground, however rich, unless it could be induced to flow freely. This wasteful method of exploitation relieved the upper beds of the cream of the petroleum in a very short time, and borings were carried to greater depths to seek more prolific sources, leaving millions of poods of oil to be recovered at a later period from the shallow strata.

To-day, 1903, fountains are not expected except in the newer districts, at less depths than 1500 to 2000 feet, and even when they occur their

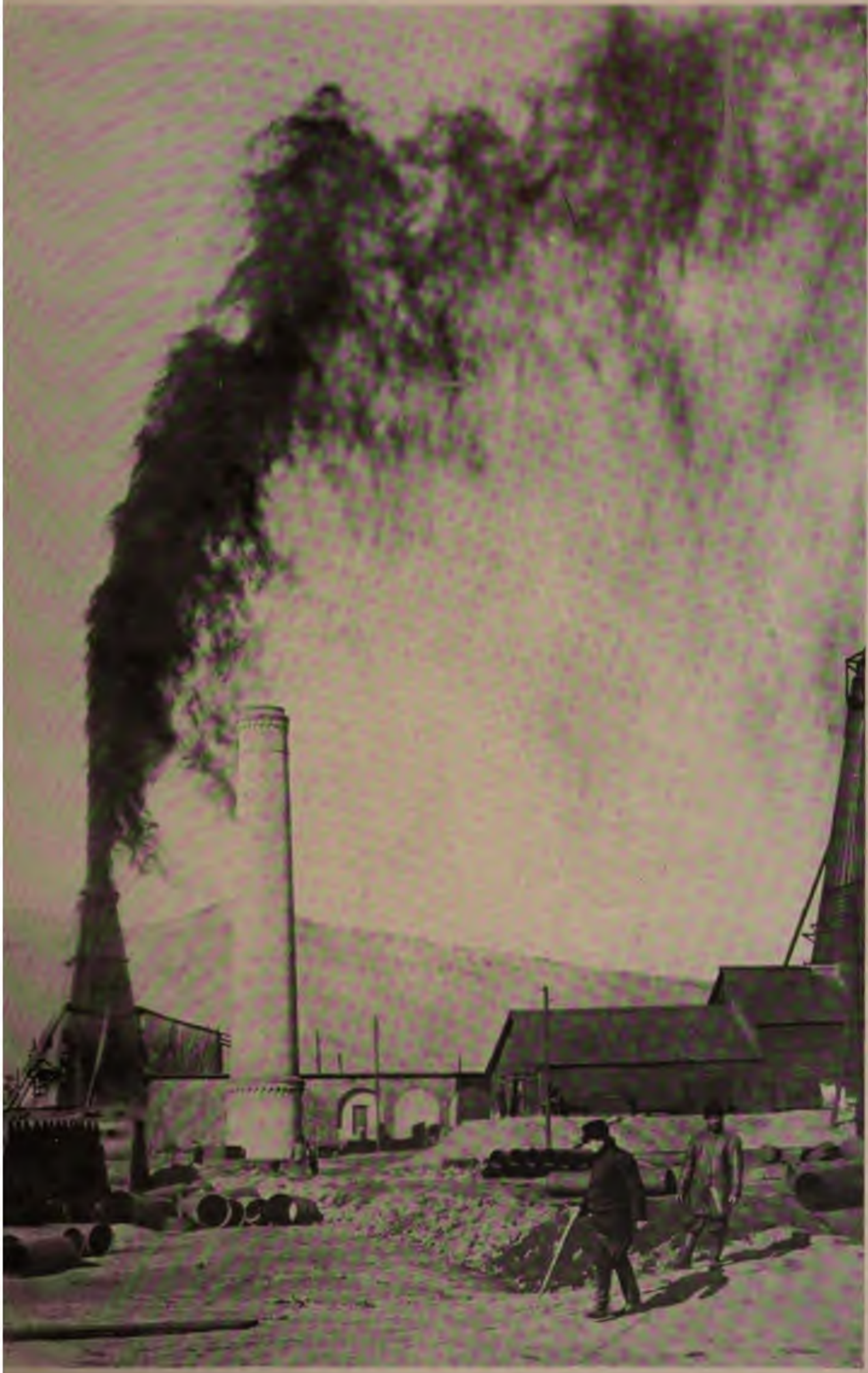

Fig. 77.—Immense Fountain in the Bibi-Eibat Oil Field.
(Yield about 1,000,000 poods = 125,000 Barrels of Oil Daily.)

[To face page 304.

appearance is not always welcomed, as they give an infinite amount of trouble on a property of limited area, and very frequently lead to the collapse of the lining tubes after violently ejecting many tons of sand and very little oil. It is now generally recognized that it is far better to have a permanent bailing well, which produces a steady, moderate output year after year, eventually exceeding that of a fountain, than a spouter that is a doubtful blessing, and which, if it does not ruin the well in a few days or weeks, often upsets the market, and brings the owner into legal actions and disputes with neighbours. A few Baku firms of distinction pursue the practice of fountain-hunting to a reckless degree, and rely to a large extent upon fountain oil for a production; but it will generally be found an expensive game to play, and statistics show that those companies that exploit their ground in a methodical fashion, and take each stratum as it exposes itself, maintain the most regular output, and secure the best return for their outlay of capital.

Official statistics show that, although the number of wells bored annually has increased from 289 in the year 1889, to 1710 in 1900, and the annual production increased from 160,000,000 poods to 600,000,000 poods in the same period, the amount of oil obtained by fountains has fallen from 68,000,000 poods to 60,000,000 poods; whereas 42 per cent. of the petroleum extracted in 1889 was of fountain origin, 12 years later only 11 per cent. was so yielded.

The wells of 1902, which are frequently 1500 to 2000 feet deep, naturally do not flow so readily as those of 600 to 800 feet; but, nevertheless, when rich new sources are tapped, fountains burst up which approach and even excel the phenomenal producers of 10 years ago, and a description will, therefore, be given of the common means adopted for their control and safety.

It may be mentioned that the first well bored at Grosny resulted in a big fountain at 430 feet, which is reported to have given 60,000 to 80,000 poods a day for a time, and to have flowed at intervals for several years. Here, as in the Baku field, the owners were quite unprepared for such an event, and the oil all flowed away to waste, the proprietor being further forced to sell the plot to meet the demands of the villagers who sustained damage by the deluge of oil flowing down a valley after breaking through the storage walls.

A rich oil source which may develop into a fountain exhibits itself in various ways, depending upon the local conditions; but in some cases the gas is so powerful that, at the moment the boring tools break through an upper impermeable stratum and penetrate the sand, they are blown completely from the well, and the whole derrick is splintered to fragments. In some instances a huge sand plug rises almost instantaneously when the drills strike the oil stratum, and buries the tools and boring rods to a depth of from 500 to 800 feet, this mishap being sometimes attended by a short period of spouting. The removal of the tools after such an accident may occupy a long time, and has generally to be performed by lowering 2-inch or 3-inch tubes and washing the sand free with water or oil at a high pressure, additional tubes being attached as the sand plug is cleared. It frequently happens, in such cases, that the plug is itself periodically loosened by the passage of escaping gas, which at intervals forces a passage through, and if full advantage is taken of these occasions, the instruments may be raised in stages without other labour. Very often no special signs are to be observed in the boring which would foretell or signify the presence of an extra prolific formation, and it is only on clearing the bore-hole with a bucket that gas suddenly rises in great volumes, producing a rapid rise of level in the well, and perhaps a fountain, before the cleaning bucket can be raised to the surface.

Then there are curious examples of wells which have yielded millions of poods of oil in a few weeks, that had, previous to bailing, shown nothing beyond a slight trace of oil and a little escape of gas, and only after months of patient bailing had oil been admitted.

Some companies make provision for a fountain in all their derricks in rich oil districts; but if there are symptoms of an approaching fountain, it is desirable to cease work at once, and make such preparations as the position of the derrick renders expedient. If the suspected well lies on the boundary of a property, and the adjoining land can neither be converted into earthen storage tanks nor hired, barriers, or embankments should be erected to prevent the oil and sand from flowing in that direction, either by high sand-banks or wooden fencing attached to piles. Large reservoirs should be excavated on the property, and the removed material should be utilized in converting more of the plot into storage space by constructing embankments, if the physical features of the property permit this. All available space should in this manner be turned into temporary ambars,* and whilst the absorption and evaporation may amount to as much as 10–20 per cent. a day, they at least afford a means of holding a large proportion of the surplus oil which cannot be delivered by the pumps into the pipe-lines. Earth storage may be very useful if carefully attended to; but it must be noted that if an embankment begins to go, nothing will preserve it, although sandbags discriminately placed on the first signs of a collapse may relieve the situation.

When running oil from one earthen tank to another, a large pipe or wooden chute should be inserted for the passage, and should be well rammed with clay to prevent leakages. When all possible storage is full, and the oil is delivered faster than the pumps can remove it, the stream should be led in chutes to either abandoned or working wells on the property, thus saving the oil from total loss, and perhaps preventing a catastrophe. The management should be provided with powerful pumps conveniently placed for dealing with the spouted oil, and arrangements should be made with all the owners of pipe-lines to lead branches to the property and make measurements of the oil in their reservoirs.

Proprietors of land on the borders of the Romany Lake have improvised very efficient storage by enclosing large areas of the water with wooden piles timbered several feet below and above the water-line. Oil admitted into these areas floats upon the surface of the water, and the timber-work, if skilfully executed, prevents any leakage of oil into the lake. Although a very convenient and cheap method of preparing storage, it is not one which should be allowed by the authorities without special restrictions, for if a fire breaks out in the vicinity, the ambars are converted into blazing furnaces, the wooden partitions are burnt, and the flaring oil is driven by the wind hither and thither over the lake.

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* This is the Russian term applied to open earthen reservoirs.

In one of the largest fires ever known in the Saboontchy field (September, 1900), when 200 derricks were destroyed, part of the damage originated from the above-named cause, for a change of the wind on the second day caused the burning oil floating on the water to be driven in another direction, where it consumed the wooden barriers of the reservoirs and ignited everything inflammable along the borders of the lake, the sparks from these fires in turn causing the destruction of many other wells.

Immediately a well starts spouting, guards should be placed all round to prevent any one with a lighted cigarette, or an evil-disposed person, from approaching; and if the well is near a public road, watchmen should be stationed to prevent smoking, to enforce a slow speed for vehicles, and to put out all carriage or cart lamps at night. All fires in houses, boiler-houses, or buildings where the gas is found to penetrate, especially on the side towards which the wind is blowing, must be extinguished, and not allowed to be ignited until all danger has passed. A large party of labourers should be at hand to clear away the sand thrown up with the oil, and to guide the stream of oil towards the reservoirs intended for its reception.

The derrick itself next requires attention. It should be timbered a second time with planks from the base to the top, the boards being placed vertically side by side, with a third one covering the joint of each two. Half-way up the derrick-posts stiff cross-timbers should be bolted to bear the weight of the locally termed "fountain blocks," which must rest thereon.

A "fountain block," or shield, is a rectangular mass of the coarsest and hardest cast-iron, 3 to 4 feet square by 12 inches thick in the centre, rounded slightly on the face which receives the force of the oil, and flat upon the upper side, which is firmly connected to two long timbers by means of four bolts arranged one at each corner. The cast-iron block mounted in this way is raised and made to lie with rounded face downwards upon the cross-timbers bolted to the main derrick-posts, and is prevented from lifting from its position by other cross-pieces bolted to the standards above, but leaving sufficient freedom for the motion of the mounted block horizontally. On one side of the derrick the timbers supporting the block are pivoted so that they may form a lever, and to the other end are attached ropes leading to a windlass, which gives the means of drawing the shield vertically over the mouth of the well when it is spouting. If a well is excessively violent, and is attended by a large quantity of sand, a natural sand-blast action is formed, which rapidly eats a hole completely through the cast-iron shield, necessitating the fixing of a second or even a third fountain block. Oak and hard wood blocks placed grain endwise have been tried and have met with success; but as there is much difficulty in procuring such large timbers as are required, and as their cost exceeds that of cast-iron, they are seldom employed.

If the fountain is intermittent in its action, the damaged block may be easily withdrawn after fixing a second block above the first; but care should always be taken to have the second one in position before the old one is removed, as it is impossible to say when the well will recommence spouting. It generally happens, however, that the fiercest fountains continue to play without intermission, and the worn and perforated block has to be replaced whilst the well is spouting. The life of the shield may be lengthened by changing its position slightly when it has been perforated in one place, and it may in this way be made to keep the well under control until another shield has been fixed. Under these circumstances, a large wooden side platform is constructed on a level with the fountain shield, and an inclined approach is built by which easy access can be gained. Carpenters, clothed in washing garments, then prepare the cross-timbers to receive the block, and work in relays in order that they may not be overcome by the gas. The work is of a most laborious and dangerous nature, for which it is usual to pay men double or treble their ordinary wages; if a man shows signs of giddiness or insensibility, he should be at once removed to a place where there is a free current of fresh air, where he will probably soon recover.

Petroleum gas, when breathed in large quantities, produces a sensation of giddiness, and unless the sufferer supports himself against the derrick he is sure to fall to the ground; but if he is removed to the fresh air the feeling wears off in a short time, although it is often followed by a strong drowsiness, in fact, an almost irresistible desire to sleep. If a workman does not recover from the asphyxiation in a short time, artificial respiration should be practised and continued until signs of life appear.

The fountain shield is elevated to the platform when the place for its reception is prepared, and to facilitate the operation of pushing it into position, the two baulks supporting the block are laid on wooden rollers or lengths of tubing. When hauled into position over the mouth of the well, the lower shield may be withdrawn or placed to one side and another cast-iron block inserted.

Fig. 78 shows the workmen engaged in pushing over the fountain shield from a side structure on a big Baku gusher.

In addition to the measures already described, a timber skeleton is usually constructed completely enveloping the derrick, covered with common boards to prevent the oil which forces its way through the spaces at the fountain shield and elsewhere from being scattered by the wind.

The arrangements mentioned for dealing with a fountain would appear to a casual observer or an American specialist to be of a very primitive and antiquated type; but it must be recollected, before passing judgment, that the conditions of the Russian oil fields cannot be compared with those of America or any other country.

A single Baku fountain sometimes yields nearly as much oil in one day as the whole output of some 25,000 petroleum wells in America, from which fact some idea of the gigantic proportions of the Apsheron wells can be gleaned.

When fountains were first struck in the Baku region, means were adopted for their regulation, and it appears that for many years, until about 1887, spouters were always shut down by means of gate-valves, and their output controlled. Nobel Bros., about the year 1883, even shut down their own wells after reaching an oil source, and bought oil for their refineries at purely nominal prices from other firms, not then realizing the loss they themselves were unconsciously sustaining. It was eventually seen that by closing their own wells they simply played into their neighbours' hands, who bored wells to the

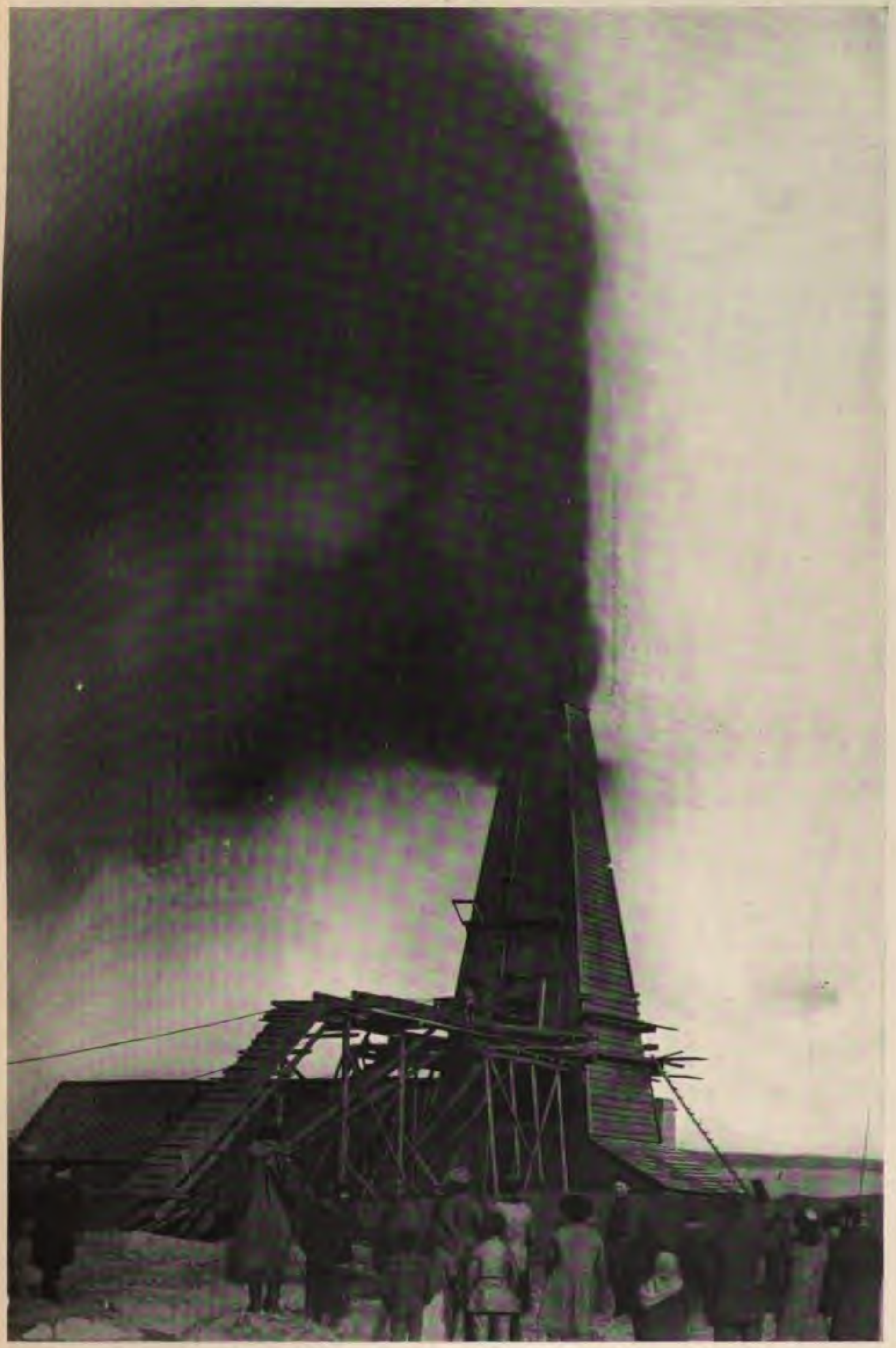

Fig. 78.—Baku Fountain, showing Workmen preparing to push over the Fountain Shield from a Side Structure.

same depth and got the oil of which Nobel Bros. should already have been the possessors. This was afterwards conclusively proved to be the case by the fact that, whenever they opened their valves and allowed the wells to flow, the fountains on the adjoining properties ceased to spout, or only played in a much smaller degree. Here, then, was one important objection to the controlling and regulation of fountains, for the total output of the field was not thereby reduced so as to lead to a rise of prices. Persons who restricted the output of their wells simply presented oil to their neighbours, and impoverished their own land to an extent nearly equivalent to the yield of the spouter. The restriction of the output was found to have no material effect in reducing the amount of sand and stones discharged, and the confined orifice led to a diminished volume of oil, and consequently a loss without any qualifying advantages. There was also difficulty in attaching stop-valves of sufficient strength to resist the destructive action of the fountains, which were accompanied with much sand expelled at a high pressure. Three or four stop-valves were attached in succession to a single bore-hole, so that when one was worn completely through the flow was diverted into a second, and subsequently, as required, into a third or fourth.

The chief objections to the controlling of spouting wells, and the reason of the ultimate abandonment of such appliances after a few years' trial, was the damage the casing sustained from their attachment, for the restriction or total extinction of the flow in numerous cases led to the bursting of the lining tubes and the cessation of discharge, and either total destruction of the well or lengthy and expensive repairs.

The pressure registered by wells when closed down varied from ten atmospheres (147 lbs. per square inch) to thirty-five atmospheres (515 lbs. per square inch), an amount rarely reached in American wells of small diameter, and sufficient to bring about very considerable damage in the presence of sand, and prohibit the use of most American devices. The impinging of the gas, oil, and sand at such a high pressure will cut a hole through a block of hard cast-iron 12 inches in thickness in a few days, and there are preserved in the Tiflis Museum a number of interesting blocks perforated in several places, which will bear testimony to the powerful sand-blast action of Baku spouters. A heavy cast-iron bend arranged to divert the stream of oil horizontally has a short existence in the face of such a destructive force.

Frequently, when fountains were closed down, a part of the gas, mingled with oil and sand, found an exit between the casings. This often occurs in spouting wells which become temporarily plugged by an accumulation of sand through which the gas cannot escape, and it seriously impedes the work of cleaning the plug and assisting the well to flow, and causes great damage to the casing. To prevent such action the space between the tubes was often plugged by driving in wooden wedges, but the plan had to be abandoned, as it led to the casing bursting from external pressure in many cases, on account of the absence of internal resistance to counteract the pressure above the level of the plug.

Nobel Bros., who are the pioneers of most innovations in the Baku oil fields, have for many years taken no precautions for dealing with fountains beyond the fixing of cast-iron shields, so that it may be assumed that they do not deem

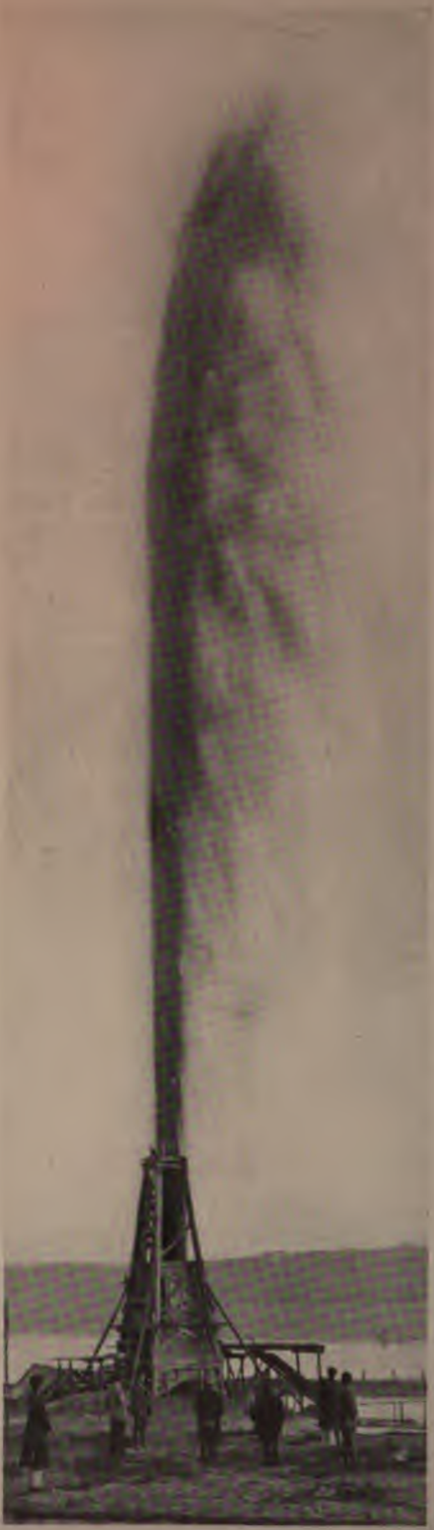

Fig. 79.—A Huge Gusher on the Border of the Romany Lake.
(Height of column of oil, about 350 feet.)

it expedient to restrict the fountains. They have, however, an exceptional system of pipe-lines, and a storage for many million poods of crude petroleum on the outskirts of the Balakhany district, so that they are able to deal with a fountain of almost any magnitude; indeed, they have successfully dealt with a fountain yielding 1,000,000 poods daily, and scarcely lost 1 per cent.

Firms less prepared for such quantities of oil suddenly thrown on their hands, with no room for local storage, find great difficulty in disposing of their oil, and they still hope to be able to find a satisfactory valve that can be employed without danger.

The risk of attaching controlling appliances may be diminished by cementing between the tubes, and thus creating a solid stone backing to the casing; but as cement cannot always be successfully used, on account of the presence of oil which cannot be removed, screwed casing might be lowered of sufficient strength to resist the usual pressures encountered. The comparatively recent introduction of screwed casing opens up a new field for the application of controlling contrivances, and they may yet be brought into general use with greater success than formerly.

The affixing of controlling devices is not likely to improve the total production of the well, and there is a slight risk in their employment, for there are recorded instances of wells once closed remaining closed always and never spouting again, the oil having been somehow shut off or diverted into other channels. One well in the eighties, which was controlled, is reported to have spouted without intermission for three years, and gave altogether about 15,000,000 poods. The amount of sand thrown up from some wells is amazing, and one old boring master described a well in which a solid core of sand, of sufficient rigidity to stand erect several feet above the mouth of the well before crumbling away, was expelled slowly upwards by an enormous pressure.

There are numerous authenticated cases of the whole of the boring tools and rods being blown completely from the well on the penetration of an oil stratum, their entanglement in indescribable confusion inside and around the shattered derrick having a most amusing appearance.

A fountain often commences by being what the Americans would describe as a "duster;" that is, it throws out sand at a high pressure for several days. The sand is freed from oil in mid-air, and covers the district with a fine white deposit, but oil generally puts in an appearance in large quantities afterwards. Many large fountains give nearly all sand, stones, etc., for days or weeks before oil is discharged in large quantities with only a small percentage of sand.

Table XXV. gives a list, with details, of the chief fountains in 1900, 1901, and 1902.

TABLE XXV.

PRINCIPAL FOUNTAINS IN 1900, 1901, AND 1902.

(Over 6,000,000 poods.)

1900.

Name of company.	Number of well.	Diameter of well.	Depth of well in sagenes.	Number and position of property.	Yield in poods.
		Inches.			
Mantasheff and Co. . . .	162	13½	237	103. Romany	15,000,000
" " . . .	74	9½	261	37. Bibi-Eibat	9,500,000
Nobel Bros. . . .	181	8	206	31. Romany	9,500,000

1901.

Baku Oil Co. . . .	3	14	259	6 B-E. Bibi-Eibat	15,600,000
Schibaieff Petroleum Co. .	4	8	262	29. "	11,300,000
Musa Nagieff . . .	6	12	210	23 C. Saboontchy	10,600,000
Mantasheff and Co. . .	190	11¼	260	103. Romany	9,300,000
Baku Russian Oil Co. . .	5	8	262	36. Bibi-Eibat	7,500,000

1902.

Assadulaieff . . .	5		227	107. Romany	9,600,000
Zubaloff	24		158	XX. Bibi-Eibat	9,400,000
Schibaieff Petroleum Co. .	4		262	29. "	8,400,000
Mantasheff and Co. . .	190		263	103. Romany	6,600,000
"Schikhoff" Co. . .	9		246	15. Bibi-Eibat	6,100,000

During the last few years a number of wells have been struck which have flowed incessantly for weeks and months, and yielded millions of poods of oil, but the frequency of such monsters is annually decreasing, and fountains now (1903) form but a small percentage of the number of wells completed. On several properties situated on the borders of the Romany Lake the gas pressure encountered in the deep, untouched beds was so terrific that, although no attempts were made to confine the outlet, well after well was torn to pieces in a few hours, and permanently injured after blowing with stupendous force. The first outburst usually carried away the whole of the upper part of the derrick, and the roar of the escaping gases could be distinctly heard for several miles around, and it was only after a large proportion of the gas had found relief in this way, and several expensive wells had been lost, that big oil producers were struck which were of manageable proportions.

When a fountain is anticipated, a strong protective column of screwed tubes should be lowered into the well, as the damage sustained by riveted casing is greatly exaggerated by the seams of the joints and the more active abrasion of the soft-iron rivets than the iron of which the tubes are composed. The presence of soft rivets produces a most curious result, for the sand-blast cuts them away and starts a series of grooves resembling those of a rifle-barrel, and tubes removed from powerful spouters have been found to be cut to shreds by perfectly vertical abrasions commencing at the rivets. A leaky rivet, in the presence of these high pressures, is eroded in the space of a few hours into an orifice large enough to insert one's hand, and the effect is not limited to a single column if situated near the surface, for the gas and sand penetrate this hole and extend the sphere of action in a divergent manner, and attack the other casing over a large area.

A fountain of moderate strength, from which all impediments have been removed, is a fine spectacle when playing on a still day. A column of oil, sand, and gas rises vertically from the bore-hole, equal in diameter to the size of the tube, to a height of 100 to 400 feet before its energy is spent, and the particles of oil and sand are dispersed and fall upon the surrounding district. The noise is deafening, and every few minutes an extra accumulation of sand plugs the bore-hole and causes a temporary lull, which is followed by a still fiercer outburst and an increased height of discharge when the resistance is removed. Around the base of the bore-hole sand steadily accumulates until the engine-shed is buried or collapses beneath the weight of the sand collected on its roof, and a conical mound is formed of soft, oily, flowing sand, which buries everything in the immediate vicinity.

Sometimes fountains are accompanied by very little sand, in which case they are usually not very strong ones, and give little trouble; indeed, one fountain of Nobel Bros., which in 1899 played for 30 days incessantly, and gave over 10,000,000 poods of oil, needed the services of only half a dozen workmen to keep the canal clear leading from the derrick to the reservoirs. The Grosny fountains also possess this character, and some which have spouted for weeks and months have thrown up scarcely any sand. This important difference between the Baku and the Grosny fountains necessitates quite different treatment, for whilst a Baku well, after once stopping, has always to be cleared of sand before it will flow again, a Grosny well will continue to spout

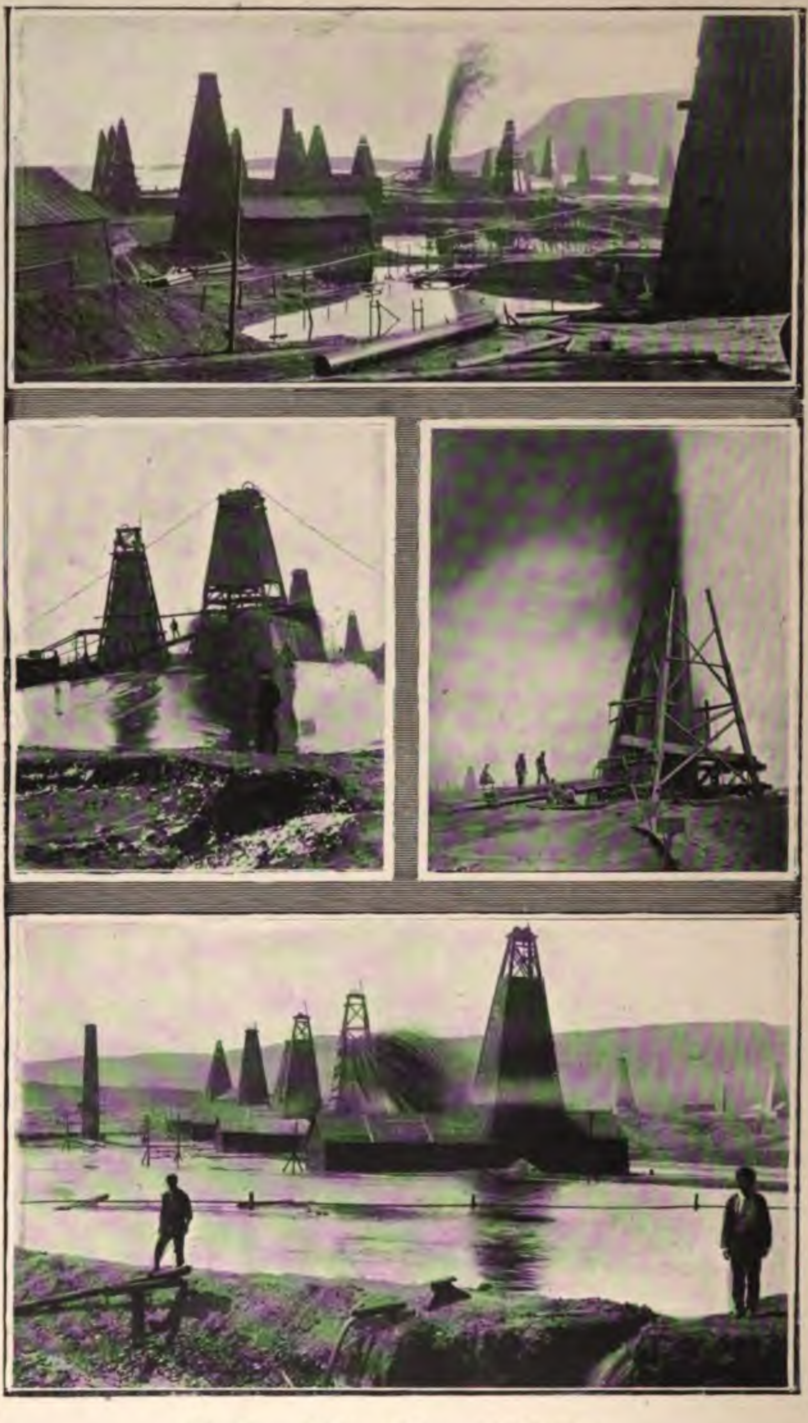

Fig. 80.—Oil Fountains at Bibi-Eibat.

1. A fountain on Plot 29, Bibi-Eibat.
2. A big spouter, showing accumulation of sand.
3. A violent spouter, which has blown away the derrick.
4. A Baku monster flowing, showing lakes of oil.

intermittently without any assistance for months, and the derrick may be locked up and left without attendance.

The greatest amount of oil which is reported to have flown from a single well in 24 hours is 1,500,000 poods (6,000,000 gallons); but although this may have occurred for one day, it seems to be an excessive amount. There are numbers of recorded cases where 1,000,000 poods (4,000,000 gallons) have been thrown up for many days in succession, and in one example, at Nobels', the pumps were actually disposing of this amount, yet for several days the oil gained on the pumps.

One of the most wonderful fountains on record, and one which may be considered one of the greatest ever yet known in the history of the petroleum industry, was that on the Russian Petroleum and Liquid Fuel Co.'s property at Bibi-Eibat; this yielded 1,000,000 poods daily for an entire month, or a total of 30,000,000 poods (120,000,000 gallons), the whole of which was stored and disposed of with scarcely any loss. The transfer of the property (Plot xix., Bibi-Eibat) from Mr. Tagieff, the original lessee, had scarcely been completed when this fountain commenced to play, which was in itself sufficient to pay a handsome dividend on the capital of the enterprise. It is difficult to appreciate such strings of figures; they can convey so little idea to an ordinary person, but the value of such a well will be better realized when it is seen that 30,000,000 poods of oil, at the low price of 5 copecks a pood, are worth over £150,000. Gold and diamond mines can scarcely compete with this, but there are several Tartar and Armenian proprietors who were the possessors of wells which yielded from 5,000,000 to 10,000,000 poods of oil in a few weeks, when oil was 12 copecks a pood, thus becoming the fortunate possessors of £60,000 to £120,000 in return for an outlay not exceeding £6000. One Tartar carter who held indisputable rights to a small plot of land in the Saboontchy district, which in 1880 could have been sold for a £5 note, leased it to an oil company that in the first year paid him £50,000 in royalties.

During the last few years (to 1903), several noted fountains have aroused considerable interest, owing to their great strength, and are worthy of a special description. In the spring of 1901, an immense fountain was struck by Messrs. Mantasheff, at Romany, which commenced with such violence that the roar was heard all over the oil fields, and many people were aroused from their sleep. The derrick was blown to splinters at the first outbreak, and a vertical column of oil and sand rose to a height of several hundred feet, flinging stones in all directions and drenching the neighbourhood with oil. The derrick and engine-house were soon hidden from view by a large mound of sand, from the centre of which the huge fountain rose, and all the houses, workshops, etc., in the district were covered with oil. Every fire within a radius of several hundred yards had to be extinguished, and the whole of the valuable properties surrounding this plot were for many days shut down, completely. Houses in the immediate vicinity were flooded out and rendered uninhabitable, and within a large circuit the drain-spouts from the roofs of buildings were pouring streams of oil into the roadways. The main roads were flooded with oil several feet deep in places, and the oil in some cases was more than a foot deep in the rooms of dwelling-houses, which the inhabitants had been forced to vacate speedily, and the roofs of which had in many cases collapsed from the weight of sand upon them.

An even more destructive fountain was one of the Baku Oil Co., at Bibi-Eibat, in 1901; this commenced to spout with terrific force from a great depth, completely wrecking the derrick, and, after rising to a considerable height, was entirely at the mercy of the winds. This fountain is estimated to have yielded about 1,000,000 poods daily for the first few days, during which time the oil flooded all the surrounding properties, and caused a total cessation of work over most of the Bibi-Eibat oil field. A changeable wind drove the oil alternately to different parts of the field, deluging miles of land, and blackening and damaging every building within its reach. A stiff breeze drove the oil towards Baku, and almost every house in Baieloff, a suburb of Baku, was blackened and soaked with petroleum, including the Russian church, public buildings, and private residences. Oil spray was falling over Baku three miles away, and sheets of note-paper exposed to the air near the railway station at almost five miles' distance were spotted with oil particles. The ships in the harbour did not escape, and the gunboats of the Caspian fleet, which are painted white, were blackened and made unrecognizable by the drifting oil spray. Although some 15,000,000 poods of oil were secured, the high duty payable to the Government, and the enormous demands for compensation from persons who suffered damage—for practically the whole of the village of Baieloff had to be cleaned and the houses repainted—left but little surplus for profit.*

Perhaps the greatest fountain ever recorded in the world's history was that resulting from Mr. Assadulaieff's first boring in Romany. This well was the first-bored hole in the district, and the oil flowed almost incessantly for years, yielding, it is reported, between 50,000,000 and 60,000,000 poods.

* The latest news from Baku reports the occurrence of a wonderful fountain on Plot 7 B-E. Bibi-Eibat, estimated to have yielded about 1,500,000 poods daily for a time. The oil eventually caught fire, and caused a fearful conflagration, in which five fountains were burning simultaneously on one day.

CHAPTER XII.

GENERATION OF STEAM.

Power on the Oil Fields.—Steam still the most general source of power—Economy of fuel at first disregarded.

Steam Boilers.—Types used, and usual dimensions.

Water for Boilers.—Companies for supply of Caspian water—Cost of such water—Private supply from the Caspian in the case of large companies—Water from oil borings inferior to Caspian water—Insuperable difficulties on using a mixture of these waters—A spring of very calcareous water on the Apsheron Peninsula—Use of surface water.

Salinometers.—Description of English and Russian salinometers—Confusion arising from different standard temperatures.

Cleaning Boilers.—Most suitable frequency—Points to be noted in cleaning—Cleaning by contract.

Precautions that should be taken with Steam Boilers.—Collapsed tubes the chief danger—Causes of collapse—Danger of crack in flange of first furnace-tube ring—Cause of this, and improvement effected by changing furnace front—Safety-valves; protective but unpractical Government regulations.

Economizers.—Feed-water heaters; description of some simple forms—Inadequacy of feed-water to abstract available heat from exhaust steam—A cheap form of surface condenser—Combination of feed-water from ordinary source heated by jet condenser, with water from surface condenser most economical on oil concern—Plan for large condenser, where such is desirable—Oil-field conditions against employment of such forms as Green's economizers—Economy by heating feed-water—Superheaters—Description—Amount of economy attainable—Objections to their use—Heating air before admittance to furnace—Arrangement tried at Baku.

Steam Lines.—Expense and trouble saved by exercise of forethought in laying out new properties—Necessity for adoption of overhead system at Baku—Standards.

Insulation of Steam Lines.—Long lengths exposed on an oil property—A favourite non-conducting composition at Baku—Hair felt—A coating successfully employed by the author—Extreme importance of covering steam lines—Conditions allowing of under-ground insulation at Grosny.

Expansion of Steam Lines.—Improvised expansion joints usually adopted.

Steam Traps or Separators.—General description.

Boiler-houses.—Site to be carefully chosen—Minimum of woodwork to be used in construction—General plan—Position of pressure-gauges—Importance of perfect disposal of all drippings and drainings—Precautions in regard to blow-off tubes.

Chimneys and Flues.—Great danger arising from employment of iron chimneys—Location of smoke-stack in reference to boilers—Dimensions of stacks.

CHAPTER XII.

GENERATION OF STEAM.

Power on the Oil Fields.—Steam has always been the predominant, and, until recently, the only power used on an extensive scale on the oil fields, nor is it likely to be superseded by electric or other sources of energy for some years, on account of its simplicity and cheapness compared with other sources of power, even under the particularly unfavourable conditions found in the oil fields. Entire absence of complicated plant for the conversion of water into steam, and freedom from all intricate attachments in the engines, commend steam for use with unskilled labour before anything else. An electric motor, an oil-engine, or a gas-engine necessitates the constant attendance of a mechanic, for ceaseless attention is needed to keep the machinery in good working order, whilst a slight defect may render them useless, and lead to hours of stoppage; but a steam-engine, on the other hand, requires, for weeks together, little more than an occasional oiling by a greaser, and will work for years in a condition and under circumstances where any other type of motor would need replacement. The relative merits of various classes of motors are discussed in Chapter VIII., where the subject is fully dealt with, and where the advantages and defects of different types are compared.

Economy in the use of fuel has not, until within the last few years, received any attention from the engineers on the oil fields, on account of the absurdly low price of oil, which gave it practically no local value. The enormously increased commercial value, smaller yield per productive well, and necessity for bailing or applying some power in nearly all cases for raising the oil to the surface, has entirely altered the aspect of the subject, and whereas formerly the ratio of fuel to output was but a fraction of 1 per cent., it has risen under the altered conditions to 8, 10, and even 12 per cent.

Steam Boilers.—Steam is generated on the Baku oil fields chiefly from 45 nominal horse-power Lancashire boilers of the common plain type, approximating in proportions to those of English manufacture. The principal dimensions are as follows:—

Length of boiler shell,	27·25	feet.
Diameter „ „	6·5	„
Furnace tubes (diam.)	2·2	„

Boilers of this description will evaporate, under normal working conditions, without economizing contrivances, between 6750 and 8100 gallons (2500 to

3000 vedros) a day, which, taking an average of 7425 gallons (2750 vedros), is equal to about 1·1 cubic foot of water per nominal horse-power per hour.

The boiler pressures are generally limited to 60 lbs. per square inch (four atmospheres) in the Baku districts, as there is an element of danger attaching to the use of high pressures, both from the employment of bad waters for the boilers and from the distribution of steam over large areas.

The French "Elephant" type of boiler has been introduced to a small extent, but, although a much greater rate of evaporation is obtained from a single boiler, there is danger in its use where local or salt water is used, and it cannot be recommended unless supplied with condensed water. The common measurements for a 72 nominal horse-power boiler are—

Length of boiler shell,	27·33	feet.
Diameter ,, ,,	6·5	,,
Furnace tubes	2·2	,,
Lower tubes	2·2	,,

The large percentage of salt in the Baku waters prohibits the erection of high-pressure, rapid-evaporative boilers, as Galloway or water-tube, but in permanent stations such as electric-power installations, where high pressures are essential for economy's sake, condensing plants have been erected, and fresh water from these is supplied to water-tube boilers. The quantity of water required to make up the loss through leakages, etc., in a good condensing engine, is very small, so that a large condenser plant is not needed. On the Grosny oil field, where there is a plentiful supply of good water, higher pressures have been successfully employed.

Water for Boilers.—The feed-water for boilers in the Baku district is generally from the Caspian Sea, which exhibits about 2 per cent. of salt in Baku Bay, or 3 ounces per gallon, whereas the ocean waters show 3·5 per cent. or 5 ounces of salt per gallon. An idea of the amount of feed-water required on the Balakhany-Saboontchy field is obtained when it is asserted that two 10-inch and one 12-inch mains are needed, through which the water is pumped from Blacktown, almost the whole supply being required for feeding boilers. A monopoly is enjoyed by a single company for the supply of water to the Balakhany oil fields, whose charge per vedro varies with the quantity taken, and ranges from something over a rouble to more than two roubles, but for a supply of 50,000 to 60,000 vedros a day the price is 1·50 rouble per 1000 vedros, equivalent to a little under a shilling per 1000 gallons. The greatly reduced price for contracts dealing with large quantities often leads to the combination of a number of firms, who thus procure the benefits derived from a large contract. The company insists on payment for a minimum amount, and will not undertake to give more than the stipulated quantity unless it is contracted for at the beginning of the year. In the Bibi-Eibat field the sea is close at hand, and the water costs very little to procure, but the water to Balakhany has to be pumped about 10 miles to an altitude of nearly 200 feet before being distributed about the district.

Many of the large companies own private pumping stations and water lines, which in a short time repay the initial expenditure, for in the case of a company requiring 60,000 vedros a day, enough to supply twenty boilers, the annual water rent would amount to £3500. A pipe-line from the sea to Balakhany, with duplicate set of pumps, capable of delivering to the oil fields 90,000 vedros daily, would not exceed £10,000, whilst the working expenses would not exceed £500 a year, provision thus being made for 50 per cent. more water than is required, for a sum repayable in nearly three years by savings effected.

Some Baku companies employ well water taken from their oil borings, from which the oil has been separated, but in the majority of cases this is much inferior to Caspian water, and cannot be economically used. In some districts the water only shows a percentage of salt slightly exceeding that of sea water, and is to a large extent collected for boiler-feed purposes; but although to all appearances harmless, it often contains chemical compounds in solution which have a very destructive effect upon the boiler plates. Attempts have sometimes been made to economize by mixing together well—and Caspian—water, but generally this mixture has led to the formation of a flint-like incrustation, which clings with extraordinary tenacity to the boiler plates, and resists all usual methods of cleaning.

A limited supply of fresh water exuding from a rock at the extremity of the Apsheron Peninsula, near Boozovna, was, in 1900, purchased by a Baku company, with the idea of supplying the oil fields with water. A pumping installation was erected, and a 6-inch pipe laid, but although it has been a great boon to have good drinking water delivered to the houses, very little use could be made of it for boiler-feed, as it forms a very hard calcareous deposit which condemns its employment. This water flows from a calcareous formation, and is highly charged with carbonate of lime, so that if it were treated with caustic lime, the bulk of the carbonates would be deposited thus: $CaH_2(CO_3)_2 + CaO = 2CaCO_3 + H_2O$. In most waters of this description, the calcium carbonate is only held in solution by the presence of an excess of carbonic acid, so that on the application of lime, a combination ensues with formation of insoluble calcium carbonate which is precipitated. This fresh-water supply is strictly limited, and in any case could not largely be taken for boilers, its chief purpose being for drinking, for which almost the whole yield is utilized.

Several oil-producing firms purchased plots of land in the neighbourhood of Mashtagi with the sole intention of utilizing the surface water which permeates the limestones over the whole of that region; but when plans were matured for the storage and delivery of the water to Balakhany, the authorities prohibited its removal on account of the damage the few gardens and vineyards would sustain if the source became dry. In a few outlying districts, where the same objection could not be raised, small quantities of water have been struck in shallow wells dug in the yellow sands overlying the oil series, and these waters are employed on a few properties.

Good water may be obtained from shallow borings on the Grosny field, but there are several flowing sulphur wells that also give a large production of water very suitable for boiler-feed purposes.

The employment of excessively salt waters for the boilers in the Baku fields renders it necessary to frequently blow off, in order that the degree of salinity does not exceed the point when salt is rapidly precipitated. The usual practice is to blow off each boiler two or three times a day, at fixed hours known from experience, but the stokers should be trained to use the salinometer, and taught to blow off when the salinity reaches a prearranged limit.

Salinometers, or Salimeters.—An English salinometer is graduated into degrees, each of which represents the quantity of salt dissolved in 1 gallon of average sea water, namely, 5 ounces. The zero point is found by immersing the instrument in fresh water at 200° Fahr., and noting the exact point of the liquid on the vertical rod, whilst a similar trial in sea water at the same temperature fixes the unit point for ordinary sea water. The reason for choosing a temperature of 200° Fahr. is because this will very closely approximate to the temperature of the water drawn from a boiler at the moment of testing the salinity. In Russia the salinometers are marked with percentages of salt, and are designed for a temperature of 15° C., so that unless the water is cooled to this degree after withdrawal from the boiler, an incorrect value is read off. The confusion arising from salinometers is recognized by the Mining Department, for in the regulations relating to steam boilers the following instructions are found:—

I. For cold water delivered into a boiler the maximum salinity allowed is—

(*a*) For sea water	2 per cent.
(*b*) For water from bore-holes or wells	6 „

II. For water blown from boilers (hot)—

(*a*) Sea water	5 „
(*b*) From bore-holes or wells	9 to 10 „

But the last two figures are really little more than half the *actual* percentage salinities when the water is cold.

Cleaning Boilers.—Even when boilers are blown off frequently, an incrustation soon forms on the furnace tubes, and a big deposit of sedimentary matter, held in suspension by the water, collects on the bottom of the boiler shell, so that it is highly advisable to close down at least once a month, for cleaning, but if the boilers have been heavily fired, not more than three weeks should be allowed to elapse between successive stoppages. When a boiler is stopped for cleaning, the water should never be drawn off hot, but left to stand until it is quite cool, as the scale is softened considerably by the long soakage it endures. If the boiler has been lightly fired, a thin incrustation only will be found attached to the plates of the furnace tubes, which really acts as a protection to the iron from injurious chemicals in the water; but a sediment will always be found at the base of the boiler, which must be cleared away if free circulation is to be encouraged. If the boiler has been overworked, a thick scale, which may exceed $\frac{1}{4}$ inch in thickness, will be found clinging to the furnace tubes, whilst from 4 to 6 inches of sediment will usually be discovered along the bottom of the shell, so that not only is the evaporative efficiency impaired, but there is danger of injury to the plates from overheating.

Boilers in Baku are generally cleaned by contractors, but before acceptance from the cleaners, the interior should be carefully examined by the engineer or foreman of the property, to ascertain whether all the corners and difficult places around the furnace tubes have been properly scaled—positions which, if neglected long, will cause damage to the boiler.

Precautions that should be taken with Steam Boilers.—The chief danger to boilers in the Baku oil fields is that of collapsed furnace tubes, and the prevalence of such accidents is proved by the large number of withdrawn tubes that may be seen lying about the oil properties in all directions, some of which have been responsible for loss of life. Collapses are generally due to the formation of a thick scale on the furnace tubes, arising from the practice of extending the period between cleaning, when steam is short; consequently, overheating of the plate ensues, and a collapse is inevitable when the heated iron can no longer resist the internal pressure. Another common cause for collapsed furnace tubes is inexcusable negligence by allowing the water to fall below the tubes, but sometimes the disaster cannot be traced directly to the carelessness of the stoker, but to lack of intelligence, and is due to the choking of the gauge-cock inlets, which are very liable to fur up unless repeatedly blown through. In any case, no excuse can be accepted for a collapse under such circumstances, as it is part of the stoker's business to periodically test the gauge-cocks and assure himself that all is right; but to minimize the danger, all boilers should be fitted with two gauge-glasses.

A frequent defect observed in the Baku Lancashire boilers is the development of a crack in the flange of the first furnace-tube ring, apparently due to unequal expansion; but as the old iron taken from this part of the rings exhibits a brittleness nearly equal to glass, there is little doubt that the iron is first spoiled by the chilling it suffers as the cold air strikes the flange whilst entering the furnace front. The common class of furnace front assists this destructive action, for the discs which constitute the furnace doors admit air through orifices cut in their outer edge, thus causing all cold air drawn into the furnace to strike upon the flange. A decided improvement will be effected by replacing the latter type of furnace front by a class that forms a light connection with the furnace ring, and admits air through a series of orifices—preferably of a regulatable character—encircling the burner. Cold air never comes in contact with this weak spot when the furnace is so designed, and the change to the latter form of plate will repay the expenditure incurred.

Two safety-valves are always attached to the boilers, one of which is mounted in such a way that it can be sealed by the Government engineer when the weights have been carefully adjusted. The law is strictly enforced, and no engineer who values his liberty would dare to break the seal and test the value of the spare safety-valve; but, nevertheless, it is worse than useless, for it gives an appearance of safety when there is none, and affords an example of the peculiarities of some of the regulations, compiled in good faith, but sadly lacking in practicability. Safety-valves, exposed as they are to atmospheric influences, very soon become rusted down on their seatings unless occasionally put in motion for a few seconds, and as no examination is ever made of those officially sealed, and years elapse before a second inspection of the boiler is needed, most of them would be entirely inoperative if their action were demanded. Every few days one of the stokers should raise each lever of the safety-valves, and let a little steam blow through.

The intense salinity of water blown from the boilers rapidly causes ordinary gas or steam piping, which is commonly employed for blow-off pipes, to be eaten away, and men may easily be scalded by the bursting of a tube in or near the boiler-house. This danger may be overcome, as well as expense saved, by using cast-iron pipes with flanged branches at intervals to correspond with the fittings on the boilers.

Economizers.—Many methods have been introduced from time to time for economizing fuel, some of which will now be mentioned; and although the exact value of the economies effected cannot always be accurately ascertained on account of the connection of a number of boilers in one battery, with all the water-feeds and fuel-pipes connected, the saving is obviously great.

Feed-water Heaters.—One of the simplest methods of economizing fuel is to heat up the feed-water for the boilers, and, considering the facilities for utilizing inexpensively some of the steam usually exhausted into the atmosphere, it is surprising what a little has been accomplished in this line. The easiest way of heating up the feed-water is to lead the exhaust pipes from the donkey feed-pumps in the boiler-house, or other engines near at hand, direct into the feed-water tub, and deaden the loud noise caused by the injection of steam by attaching to the extremity of the discharge pipe a vessel containing a quantity of pebbles. When this simple arrangement is made, provision for admitting air into the exhaust pipe must not be forgotten; it is performed by drilling a small hole somewhere, otherwise when the engine or pump is stopped condensation sets in, and water is drawn up into the cylinder.

A very simple, cheap, and efficient feed-water heater may be constructed by uniting several lengths of old 28-inch or 30-inch well casing, or old boiler furnace tubes, and affixing by means of bolts through flanges a cover and bottom base-plate. Through the top plate the feed-water is led and dispersed evenly over the chamber by a spray, and into the base is conducted the exhaust pipe from one or several engines or pumps; an outlet pipe in the bottom conveys the products away in a boiling condition, and an exit tube in the cover allows any air and uncondensed steam to escape. A jet condenser heats the feed-water up to a high temperature, if properly controlled, and it possesses the advantage of returning condensed water to the boilers, thus diminishing the salinity and materially augmenting the supply; but precautions should be taken to skim off regularly the oily scum which always collects upon the surface of condensed water, as it has a destructive effect upon the boiler plates. The exhaust steam from a single 14-inch by 18-inch double-cylinder steam-engine, bailing a large well, contains sufficient heat to raise the temperature of over 30,000 gallons of water from 60° Fahr., to 200° Fahr., and will itself augment the supply of feed by 5000 gallons of pure water daily. A 10 to 12 per cent. economy is effected by the heating of the feed-water; a saving of several shillings a day is made for water; and the frequency of blowing off, with its consequent great loss of heat, is reduced.

As the feed-water is quite inadequate to condense more than a very small proportion of the steam escaping from the engines, the capacity of a jet condenser is limited, and recourse must be had to a form of surface condenser in which impure varieties of water may be substituted for good water. A cheap form of condenser answers the purpose quite well, for ordinary 2-inch gas-pipes may be used instead of small copper tubes, and the main shell can be converted from an old Cornish boiler. Mud-holes must be provided for the removal of sediment; a small aperture should always be left open at the top of the condenser to permit the escape of any air which may collect; and a large-area, low-pressure safety-valve should be attached either to the condenser or near by to allow the steam to blow off if the back pressure exceeds a nominal amount. A vacuum condensing plant is generally out of the question on an oil property, and a combination of a surface condenser to furnish a supply of fresh water, with a jet condenser to heat up the ordinary feed-water before admixture with that derived from the condenser, constitutes the maximum of economy that can be attained in this way on an average oil concern.

When a large condenser is planned for procuring a supply of fresh water from exhausted steam, a large central main is led along the property, constructed, for the sake of cheapness, from old 12-inch to 16-inch well casing, riveted together in about 30-feet lengths, and connected by bolts passing through angle-iron rings at their extremities. The whole line is carefully caulked and given a slight fall towards the condenser, in order that water shall not accumulate after condensation; and although it is more convenient to place the main below ground on an oil property, the cooling effect of the atmosphere is lost, and better results will follow its erection upon pillars. At suitable intervals along the central main small flanged cast-iron brackets are attached, which give a means of simply coupling up the exhaust pipes from the engines; but a stop-valve must be interposed between each engine and the main, so that repairs to the engine can be executed without steam issuing from the ports, etc.

Green's economizers and other feed-water heaters, which are suitably-designed systems of tubes placed in the flue leading to the chimney, have not been erected on the oil fields, for the reason that there are not sufficient advantages over steam to warrant the extra outlay such an installation implies; but the waste products of combustion are sometimes utilized in a similar way to superheat the steam. It must not be forgotten that in all cases where the feed-water is raised to a high temperature, or where it may at times reach the boiling-point, the precaution must be taken of fixing the feed-water tank on a level with, or slightly above the level of, the donkey-pumps, as, of course, a pump will not draw boiling water on account of the formation of steam when the pressure is reduced. Donkey feed-pumps fitted with resinous packed plungers must have their pistons replaced by others provided with metal rings or other material unaffected by hot water.

The saving secured by heating feed-water should appeal to every engineer on an oil property, and considering the facilities that exist for employing exhaust steam to perform this duty, and realizing the advantages that accrue from adding a proportion of condensed water to the ordinary sea-water feed, it is surprising how few companies have taken any steps in the matter. By heating water from 60° Fahr. to 200° Fahr. a direct economy of about 12 per cent. is effected in the fuel consumption, or a saving of approximately 0·87 per cent. is obtained for every 10° Fahr. the feed-water is raised in temperature.

The following table, showing economy effected by heating feed-water, is taken from Kempe's "Engineers' Year-Book:"—

TABLE XXVI.

Percentage Saving of Fuel by heating Feed-water.

(Steam at 60 lbs.)

Initial temperature of feed-water.	Final temperature of feed-water (degrees Fahr).						
	120°.	140°.	160°.	180°.	200°.	250°.	300°.
32°	7·50	9·20	10·90	12·36	14·30	19·03	22·90
35°	7·25	8·96	10·66	12·09	14·09	18·34	22·60
40°	6·85	8·57	10·28	12·00	13·71	17·99	22·27
45°	6·45	8·17	9·90	11·61	13·34	17·64	21·94
50°	6·05	7·71	9·50	11·23	13·00	17·28	21·61
55°	5·64	7·37	9·06	10·85	13·60	16·93	21·27
60°	5·23	6·97	8·72	10·46	12·20	16·58	20·92
65°	4·82	6·56	8·32	10·07	11·82	16·20	20·58
70°	4·40	6·15	7·91	9·68	11·43	15·83	20·23
75°	3·98	5·74	7·50	9·28	11·04	15·46	19·88
80°	3·55	5·32	7·09	8·87	10·65	15·08	19·52
85°	3·12	4·90	6·63	8·46	10·25	14·70	19·17
90°	2·68	4·47	6·26	8·06	9·85	14·32	18·81
95°	2·24	4·04	5·84	7·65	9·44	13·94	18·44
100°	1·80	3·61	5·42	7·23	9·03	13·55	18·07
110°	0·90	2·73	4·55	6·38	8·20	12·76	17·28
120°	0	1·84	3·67	5·52	7·36	11·95	16·49
130°		0·92	2·77	4·64	6·99	11·14	15·24
140°		0	1·87	3·75	5·62	10·31	14·99
150°			0·94	2·83	4·72	9·46	14·18
160°			0	1·91	3·82	8·59	13·37
170°				0·96	2·89	7·71	12·54
180°				0	1·96	6·81	11·70
200°					0	4·85	9·93

Superheaters.—Superheaters are occasionally fixed to reduce the condensation which takes place in the mains, and convert into steam the particles of water carried over through the boilers priming. They consist generally of a system of tubes placed in the main flue leading from the boilers, through which the steam is compelled to pass and undergo a severe heating, when it is freed of all particles of water and converted into a more perfect gas, before entering the property service mains. By superheating, a 10–15 per cent. economy is attained if the lines are properly insulated and not too long; but the chief objection to the use of superheaters lies in the irregular delivery of steam due to the intermittent working of the engines and pumps on the properties. At one moment the flow of steam is rapid, whilst at another moment there is almost stagnation—a condition which puts a severe strain on the joints, by unequal expansion, that is liable to lead to much trouble.

Heating Air before Admittance to Furnace.—Another method of economizing fuel, which has been tried in Baku, is to admit to the furnaces only air heated to a high temperature—an end that is secured by conducting the air through tubes built in the side flues of the boiler, before permitting it to enter the furnace cover. The furnace front must be specially designed to admit the heated air through apertures surrounding the burner, and be provided with connections which allow rekindling and adjustment of the flame with ease.

As the combustion of each pound of fuel requires about 15 lbs. or 200 cubic feet of air, all of which has to be raised from the temperature of the boiler-house (say 70° Fahr.) to the temperature of the furnace, a considerable economy must accrue if the air can be heated, prior to admission to the furnace, by means of hot waste products of combustion.

Steam Lines.—The distribution of steam on oil properties is most economically carried out by the erection of a large main pipe located as nearly as possible along the centre of the plot, from which branch lines can be led to the various wells or clusters of derricks. On laying out a new property, ample provision for new borings and accessories should be made when calculating the sizes of the steam mains, otherwise innumerable inconveniences and continuous expense will be incurred. Many of the Baku oil properties, laid out without any thought for the future, have, when viewed from above, the appearance of a spider's web, being overrun by small steam tubes radiating from the boiler-house in all directions; these lumber up valuable land and constitute an everlasting expense for maintenance. It is much cheaper to arrange one or two 6-inch or 8-inch lines, in a central position, fitted with **T**'s at convenient intervals, ready for future requirements, than to run a new 3-inch or 4-inch pipe-line to every new well constructed.

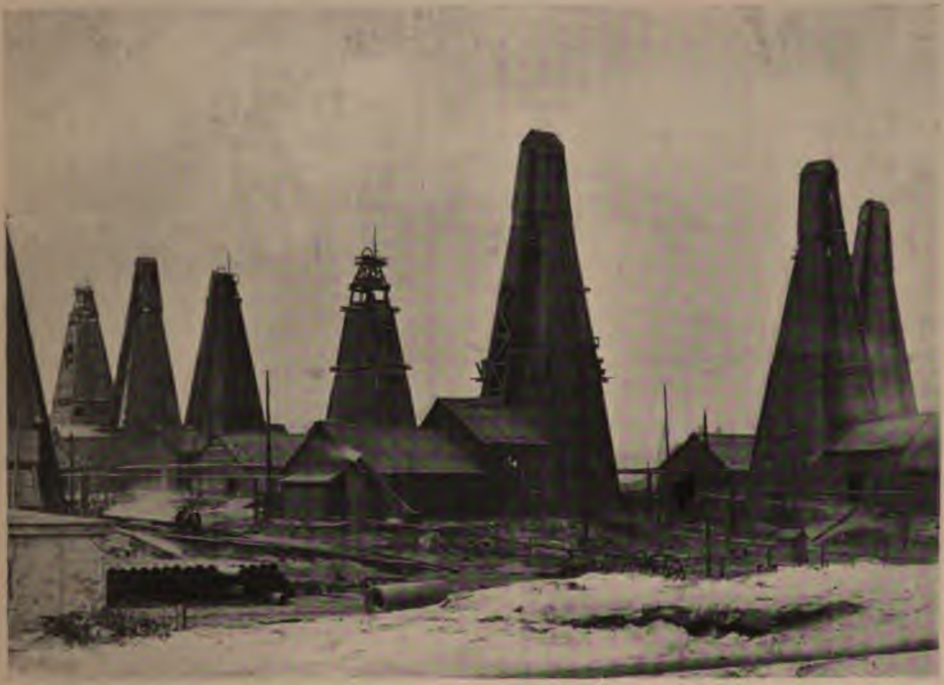

Fig. 81.—A Saboontchy Oil Property, showing Arrangement of Steam Lines erected on Iron Standards.

Steam lines in the Baku oil fields are almost invariably placed overhead, and generally supported upon wooden standards, for, except in unusually favourable spots, the rain in the winter months would cause great condensation in underground pipes. The constantly changing ground-level of an oil property, caused by the enormous accumulations of sand raised from bailing wells, renders it advisable to adopt overhead systems, as surface or underground pipes would in a few years be buried beneath many feet of sand, and be difficult and expensive to reach for repairs and connections. The overhead method is, therefore, universally in use; but the wooden supports which are so popular should be replaced by standards of a fire-proof description, because the former are always destroyed in the event of a fire, and the steam lines fall in all directions and become considerably damaged, whereas the latter would have escaped uninjured. Some firms have built brickwork columns to sustain the weight of the tubes, but this is an expensive and rather clumsy arrangement, which can be avoided by using old 8-inch, 10-inch, 12-inch, or 14-inch well casing for supporting main lines, and 5-inch to 6-inch old steam tubes for the minor branch lines—an arrangement which gives a neat appearance to the properties. The tubes are connected together in sufficient numbers to give the requisite height above ground and necessary support in the soil, and at the top a **V** or oval-shaped gap is cut wherein the steam pipe may rest without danger of displacement. Non-inflammable standards for steam lines should never be omitted on congested properties, for the destruction of steam lines by a fire hinders the restarting of work for a long time.

Insulation of Steam Lines.—The long lengths of steam lines exposed to the atmosphere on a large oil property make it necessary to encase them with an insulating material that is both non-conducting and unaffected by climate or rough treatment, and failure to do this properly not only leads to a greatly increased consumption of fuel, but to frequent broken cylinder covers and pistons from water admitted to the cylinders. A very popular non-conducting covering in Baku is prepared by mixing infusorial earth, flour, and water together, which form a paste that can be plastered around the steam pipes to a thickness of an inch without difficulty. Canvas strips are wound round the mixture and bound on by string, after which a coat of some preservative mixture is applied to prevent rotting. Tar, which is generally used, instead of preserving the covering, causes rotting, and in all cases where it is used, the string and canvas are destroyed in a few months and the insulating material crumbles away.

Hair felt, which owes its non-conductive qualities to the presence of innumerable interstices between the fibres that are filled with air—one of the best non-conductive substances known—that cannot circulate, is about the most effective insulating preparation in the market. Sheets of hair felt may be wrapped round the steam pipes several times, and bound on with canvas strips and string; but this also needs a protective covering, for unless preserved from atmospheric influences, rapid rot sets in and destroys its value.

One system is to place lengthwise along the steam pipes laths of wood, about $\frac{3}{4}$ inch by $\frac{1}{2}$ inch, separated by spaces of about $\frac{3}{4}$ inch, and after binding with fine string, to plaster well over with the before-mentioned infusorial earth paste so as to form an even surface, over which sheets of specially prepared water-proof felt are wound and secured by fine brass or galvanized iron wire.

The author has successfully employed a coating of about half an inch of infusorial earth plaster, followed by several thicknesses of hair felt bound on by string and strips of canvas, serviceable protection being supplied by a sheathing of thin iron sheets, prepared with boiled oil, and held in position by a tongue slipping into the overturned edges of the plates on the under-side. Such a covering reduces radiation to a minimum, and the sheet-iron casing forms a useful protection against atmospheric conditions and accidental knocks, whilst it can be cheaply tarred or painted with oxide of iron once a year for preservation.

No expense should be grudged for covering all steam lines in an efficient manner, as the outlay is quickly repaid by diminished consumption of fuel, and improved working of the engines. It is not uncommon to meet with properties on the oil fields, where the gauge registers no more than 20 lbs. at the engine when there is a 60-lbs. pressure on the boilers, the remaining 40 lbs. being lost by friction in small mains and condensation in imperfect or carelessly insulated pipes. Asbestos and some of the other materials so commonly used in England are debarred from common employment in Russia on account of the excessive charge made for them.

In Grosny the oil properties are located on the sides of steep hills, and rain water runs away immediately into the valleys, so that there are not the same objections to the underground system of distributing steam. The pipes are either well insulated and laid on the surface of the ground, or lowered into shallow troughs and well packed round with cinders, ashes, and clay.

Expansion of Steam Lines.—When arranging long steam lines, expansion must not be overlooked, and one or two expansion joints must be inserted at convenient points to intercept the expansion and contraction inseparable from long lines. A turned cast-iron joint with gland and stuffing box gives the neatest appearance to the main; but engineers usually improvise an expansion joint by constructing a large coil, interposing a length of flexible metallic tubing, or forming a **U**-loop by the union of four bends. Where a coil or **U** is employed, a drain-cock or steam trap should always be provided for the escape of any condensed water that might collect.

Steam Traps, or Separators.—Even where moderate precautions have been taken to procure dry steam, a certain amount of condensation always takes place in long steam lines, which water it is advisable to separate from the steam before the engine is reached. Steam traps, or separators, are interposed in the steam service for the purpose of removing water from the steam and preventing accumulations in the mains, and these can be placed, with economical results, at the extremities of all long lines.

The principle of all separators is practically the same. They consist of a vessel, fitted with baffle-plates, through which the steam passes and deposits the particles of water in suspension when impinging on the discs. The water accumulates in the lower part of the vessel, where a device is attached by which a valve is automatically opened when the quantity of water reaches a prearranged point, and allows the contents to be discharged; but the valve closes again when the water is nearly all expelled, and prevents any escape of steam. The automatic action is usually attained by the difference of expansion of two metals; the comparative cool water, when above a certain position, causing the contraction of a rod or ring and the opening of a valve connected with it; but an opposite effect is produced in the presence of steam only—the valve is firmly pressed on to its seating.

Boiler-houses.—Boiler-houses on the oil fields should be erected in a carefully chosen locality on the property, or preferably on an adjoining plot not exploited, and should be designed with a minimum of woodwork in order that they may not be a source of danger to the wells if a fire originates in them.

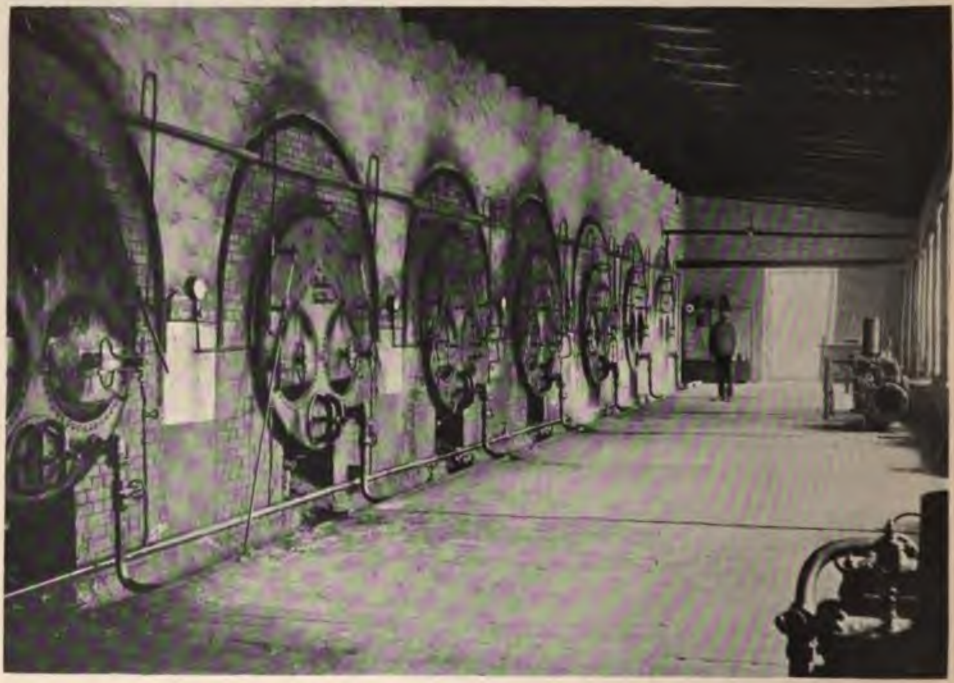

Fig. 82.—A Typical Baku Boiler-house fitted with eight 45-H.P. Lancashire Boilers.

The building itself should be lofty and wide, and constructed of stone or brickwork; the window- and door-frames should be of cast-iron; at least two doors, one at each end, should be supplied to allow a draught through, and to admit easy escape of the attendants in case of an accident; the roof should be made of angle-iron or T-iron, with a corrugated galvanized-iron covering, or a sheathing of plain sheet-iron dipped in boiled oil and painted; large, efficient ventilators should be provided to render the stokers' occupation bearable in the long summer months. The structure should be planned so that additional boilers can be added without delay and without any disarrangement of the existing smoke-flues, steam, feed-water, or blow-off pipes, or alterations to any original fittings. Spare, donkey-feed pumps must always be fixed to prevent a stoppage through failure of a pump, and the pipe connections should be so fixed that disconnection and renewal can be simply executed.

The pressure gauges should not be fixed on the front of the boilers, as the glare from the furnaces makes it very difficult to distinguish the reading, but to one side, where they are clearly visible. At the side of each boiler a small blackboard or slate should be attached to the wall, giving the number of boiler, date of official test, and time for next official test, and upon this should also be written the date of last cleaning, the number of days fired, and any other observation worthy of note that has occurred since the last cleaning, so that the engineer or his assistants can see at a glance the particulars relating to each individual boiler.

An inclined brickwork or masonry drain must traverse the full length of the boiler-house to take the oil drippings and blowings from the various pipes connected with the fuel and steam feeds. The drain should be furnished with a water-flush that can occasionally be turned on, and the drainings should be conducted to a spot where there is absolutely no danger from fire, and not allowed to collect in an earthen pit near to the boiler-house or in proximity to other inflammable materials. Failure to adopt these elementary precautions often leads to fire, and in 1900, such carelessness was the cause of a conflagration that destroyed about forty derricks and much other property in the Saboontchy district.

The fuel tanks should be discreetly placed where they are entirely out of reach of the influence of the boiler fires, and in such a position that the drainings from the vessels can be led out of danger.

The blow-off pipes should be situated outside the boiler-house, and conducted a long way from the building or other metallic work, into a wooden tub, with exits for the water and steam, for any salty spray driven by winds has a most disastrous effect upon ironwork, and eats away an ordinary sheet-iron roof in a few months.

Chimneys and Flues.—Smoke-stacks on an oil property should always be constructed of brickwork, and upon no consideration should iron chimneys be allowed, on account of the danger from sparks or overheated iron that attends their employment. The cool air driving against the outside of the thin iron chimney cools it to such an extent that soot is readily deposited on the interior, and it there forms a composition which at intervals becomes dislodged, and is carried away by winds, in a red-hot state, to dangerous situations. The smoke-stack should be erected upon a large concrete foundation, and should not be located too near the boilers, in order that the flues leading from the separate boilers may be given a gentle curve into the main flue, and not directed at a sharp angle. All corners or sharp angles, or other arrangements that might induce cross-currents in the flues, and so reduce the velocity of the gases, should be avoided; and if two entrances to the smoke-stack are unavoidable, a partition wall must divide the base, and direct the gases vertically upwards.

Theoretically, petroleum fuel requires nearly 30 per cent. more oxygen for complete combustion than an equal weight of coal does; but as there is not the necessity for such a surplus supply of air in the use of oil as in coal, the formulæ for the dimensions of coal-consuming flues apply to those of oil.

Molesworth's formula—

$$A = \frac{15F}{\sqrt{H}}$$

where A = area of top of chimney in square inches, F = lbs. of petroleum burnt per hour, H = height of chimney in feet—gives results which answer well in practice, and are quite on the safe side. This formula gives an area of 3·7 square feet for each 45-H.P. boiler working at its highest capacity with a chimney 100 feet high; but where a number of boilers are connected together, the area of the chimney may be reduced to 3–3·5 square feet per boiler, or the formula may be altered to—

$$A = \frac{12F}{\sqrt{H}} \text{ for ten or more boilers; or } A = \frac{13F}{\sqrt{H}} \text{ for five or more boilers.}$$

Liquid fuel is not so dependent upon draught for complete combustion as coal, owing to the ejection of the finely divided fuel into the furnace by a jet of steam or compressed air, consequently there is not the same need for high chimneys as with solid fuel, where, generally, the combustion of the fuel depends upon the draught created by the chimney.

CHAPTER XIII.

THEORY AND PRACTICE OF LIQUID FUEL, AND NOTES ON PETROLEUM GAS.

Method of burning Liquid Fuel.—Use of residuum, or astatki, as fuel—Method of burning liquid fuel—Arrangement of fuel-tanks—Need for fire-brick furnaces in some cases.

Theoretical Calorific Value of Oil Fuel.—Ultimate composition of Russian oil—Some of the reactions involved in its combustion—Calorific effect—Relative value of steam and air as pulverizing agents—Effect of moisture on thermal value of oil fuel—Effect of impurities on thermal value of fuel—Formulæ for calculating calorific value of fuel.

Evaporative Efficiency of Oil Fuel in Practice.—Chemical and thermal investigations to obtain data for comparison—Special conditions when fuel is burnt under boiler—Comparison with results obtained from coal—Rough conditions on oil field—Loss in distribution of steam.

Types of Liquid-fuel Burners.—Indefinite number of burners patented—Classification into mechanical sprays, spray burners, and vapour burners—Remarks on each class.

Advantages attending the Use of Liquid Fuel.—Little incentive to return to solid fuel after employing liquid fuel—Tabular comparison of oil and coal fuel—Definite advantages of liquid fuel.

Petroleum Gas.—Advantages attending use of petroleum or any gas—Description and data referring to the Pintsch system of generating petroleum gas—Advantages of the Pickering gas-generating plant—German gas plant in Baku—Comparison of three separate gas-generating installations at work in the Baku oil fields.

CHAPTER XIII.

THEORY AND PRACTICE OF LIQUID FUEL, AND NOTES ON PETROLEUM GAS.

Method of burning Liquid Fuel.—The term "liquid fuel" is here applied to that class of hydrocarbons which is known under the name of petroleum or petroleum products. At one period only refined distillates were employed, but after a time it was discovered that the residue, which was always treated as waste material and thrown away, could be burnt, and made to generate great heat. It is this residuum, commonly known in Russia as *astatki*, that is usually denominated liquid fuel; but on the oil fields, far removed from the refineries and unimpeded by restrictions, the crude oil as it is raised from the earth is employed for the generation of steam.

In the first trials with liquid fuel the petroleum product employed simply ran into the base of the furnace and burnt away; but afterwards a spray of steam was caused to strike the admitted oil and disperse it in a finely divided state over the floor of the furnace. Both crude oil and astatki are to-day burnt by means of a burner or steam injector, consisting of a central circular aperture, from which the oil exudes, surrounded by an annular orifice through which a blast of steam issues. Both the oil and steam inlets are regulated by cocks, which give the attendant the means of adjusting the proportions, so that a partially vaporized and atomized jet is diffused into the furnace, producing, when ignited, a brilliant flame. There are numerous varieties of liquid-fuel burners offered for sale, for each one of which special features are claimed not possessed by others; but in the Baku oil fields the simplest form of injector that pulverizes the oil effectively is the one in most constant demand. The arrangement of the burners on the boilers is seen in Fig. 82. Proper measures must be taken to obtain dry or superheated steam, partly for reasons that will be stated later, and partly because moisture in the oil leads to the extinguishing of the flame. The stoker lights the burner by pushing into the furnace a piece of burning tow attached to the end of an iron rod, after opening the steam and oil valves; but he should stand to one side, and not in front of the furnace, as a slight explosion often takes place, and may discharge a sheet of flame into his face and cause dreadful injuries.

The oil-fuel tanks must be placed at a sufficient height to induce a flow by gravitation to the burners; they must be of sufficient capacity to allow the water and mud in suspension to settle freely, otherwise water will extinguish the flame, and mud will choke the fine orifices in the burner; and they must be provided with drain-cocks to run off the separated water and sediment. When astatki (residue sp. gr. 0·920 or over) or heavy oil is employed as fuel, steam-pipes must be passed through the fuel-tanks to render it sufficiently fluid to flow, for such oils congeal in cold weather.

With some types of boiler and some classes of burners a fire-brick furnace and baffle-plate are an essential adjunct to the use of oil fuel; but where the plain injector is used, the flame is simply directed horizontally in the centre of the furnace-tubes of the Lancashire or Cornish boilers, and not caused to impinge on any surface in its path.

Theoretical Value of Oil Fuel.—Before discussing the problem of liquid fuel further, it would, perhaps, be better first to consider the subject theoretically, and then see how the results obtained in practice compare with those that theory would lead us to expect.

An average sample of Russian oil from the Baku district contains—

Carbon . . .	86 per cent.
Hydrogen . . .	14 „
Oxygen . . .	trace (not taken into account)

The oxygen, which varies from 0·1 per cent. to 1·2 per cent., is not considered here, but its effect upon the combustion is stated later. The petroleums from different districts vary, and some contain sulphur and nitrogen as impurities; but for all practical purposes the above percentages suffice. When heat is applied to a pulverized spray of oil in the presence of oxygen, or a plentiful supply of air, an active chemical reaction ensues, due to the dissociation of the constituents of the petroleum and the formation of more stable oxidation products, the reaction being accompanied by the evolution of intense heat and a high luminosity. It is impossible to say exactly what takes place in the combustion of petroleum, but it is surmised that certain hydrocarbons of a gaseous nature are liberated primarily, the character of which depends upon the class of burner and the design of the furnace, and these are burnt at a later stage with the emission of considerable heat. Whatever the reactions in the furnace itself, the final result is the same, oxygen being abstracted from the atmosphere, with the formation of carbon dioxide and water, diluted with free nitrogen; thus—

$$C + 2(2N_2 + O) = CO_2 + 4N_2$$
$$H_2 + (2N_2 + O) = H_2O + 2N_2$$

Any carbon monoxide formed in the furnace would turn to carbon dioxide in the presence of excess of air, whilst the water would pass off as steam with the waste products of combustion.

Now—

1 lb. of carbon requires 2·66 lbs. of oxygen to form 3·66 lbs. of CO_2
1 lb. of hydrogen „ 8·00 „ „ „ 9·00 „ H_2O

therefore, if it is assumed that the same reactions take place when petroleum is burnt, the following products will be formed—

0·86	lbs. of carbon require for complete combustion	2·29	lbs. of oxygen
0·14	„ hydrogen „ „ „	1·12	„ „
1·00	„ petroleum „ „ „	3·41	„ „

As the atmosphere contains only a little less than 23 per cent. (by weight) of oxygen, it follows that $\frac{100 \times 3{\cdot}41}{23} = 14{\cdot}82$ lbs. of air, or $14{\cdot}82 \times 13{\cdot}14 =$ 194·7 cubic feet of free air at normal temperature and pressure are needed to combine chemically with, and complete the combustion of, 1 lb. of petroleum.

When 1 lb. of carbon is burnt to carbon dioxide, 14,500 British thermal units are evolved, and in the conversion of 1 lb. of hydrogen into water, 62,500 heat units are liberated, so that in the combustion of 1 lb. of petroleum, disregarding the heat absorbed in dissociating the carbon and hydrogen—

0·86 × 14,500 = 12,470 units of heat are liberated from the carbon
0·14 × 62,500 = 8,750 „ „ „ „ hydrogen
A total of 21,220 „ „ „ „ petroleum

Therefore the theoretic evaporative power of 1 lb. of crude petroleum from and at 212° Fahr. is 21,220 ÷ 966 = 22 lbs. of water (bearing in mind the above-named qualification). The theoretic evaporative power of good quality steam coal is only 15 lbs., so there is an increase of 46 per cent. in the evaporative efficiency of petroleum over coal, when the values are based upon the carbon presenting itself in the form of a solid in both cases.

It was for many years the practice of engineers to calculate the calorific value of fuels in the above manner, but recent investigations have proved that the supposition that carbon is present in a solid form is not quite correct even in solid fuel, and that it is still further removed from the truth in the case of liquid fuels. There are reported examples where an evaporation of 25 to 40 lbs. of water per lb. of fuel have been obtained, but such efficiencies have never been supported by suitable evidence, and although complex chemical actions may take place in the furnace of a boiler during the combustion of liquid fuel, it seems unlikely that they seriously affect the final number of thermal units liberated.

As the carbon is present in the fuel in a liquid form, combined with hydrogen, a number of heat units are rendered available for external work, which would otherwise be utilized for the conversion of solid carbon into the liquid state; indeed, the excess of heat necessary to convert solid carbon into gaseous carbon over that necessary to convert liquid carbon into gaseous carbon, minus the amount required to dissociate the carbon and hydrogen, is the actual balance of heat available. Many theories and suggestions have been forthcoming to explain the reactions in the furnace, some maintaining that the chemical action set up between the heated steam and the atomized hydrocarbons cause dissociation of the former, and production of hydrocarbons with high calorific value, whilst others trace the special heat to the formation of exothermic hydrocarbons in the front part of the furnace, and their combustion in the back. Most of the ingenious theories lack a practical basis; water cannot be dissociated without the absorption of great heat (more than 7000 B.T.U. being absorbed in the dissociation of 1 lb. of water), which can only be withdrawn from the heat of the furnace; but even if it were, the nascent oxygen would reunite with other hydrogen and give out the same number of heat units as were absorbed in its dissociation. Steam is not and can never be a fuel such as some theories of combustion would make it necessary to admit. In like manner, endothermic and exothermic hydrocarbons may be formed during the combustion of petroleum, but heat absorbed or liberated at one point in the furnace is only liberated or absorbed at another part of the furnace, so that no advantage accrues from their formation as regards the actual number of heat units available for work. The bomb calorimeter gives results which coincide very fairly with those obtained by the simplest chemical investigations on the combustion of fuel in a furnace, when due allowance is made for impurities in the oil and conditions of combustion, and this fact discourages the view that complicated combinations and dissociations always occur in practice, which modify the thermal value of the fuel.

It is often asserted that undeniable proof exists of the varied chemical reactions which result from the combustion of fuel in different types of burners and furnaces, by comparing the widely divergent evaporative performances per unit of fuel in the same boiler; but this, in the author's opinion, is not due to the combustion of the fuel in an unusual way, but to the removal of the point of maximum temperature to a different part of the boiler furnace. The author has had, for about 5 years, no less than forty 45-H.P. Lancashire boilers under his immediate observation, every one of which was fed by liquid fuel, and from experiments conducted from time to time with the aim of economizing fuel, he has been able to gather many interesting facts.

Trials with all classes of burners which pulverize the admitted petroleum in an effective manner proved that perfect combustion of the fuel resulted if the supply of steam and oil was proportioned correctly, and the fuel burnt was not allowed to exceed the capacity of the furnace. Whether the pulverizing agency is dry steam, superheated steam, cold air or hot air, the combustion is complete, provided the adjustments are carefully handled, but the character of the flame alters in colour, luminosity, and shape, with each change of the atomizing material. So long, therefore, as perfect combustion of the fuel ensues, it is impossible to expect a greater evolution of heat, but an important matter to discover is whether the combustion takes place where the boiler can abstract the maximum quantity of heat from the flame and gases, or whether parts of the boiler are thrown out of useful employment by the delayed burning of the fuel. It is also important to ascertain whether impurities in the oil, that might be easily extracted, absorb heat from the flame, and whether, even if combustion is perfect, the greatest number of heat units are liberated where they can produce the greatest effect.

It is certain that in practice a part of the calculated heat units are not available for external work. The hydrogen, in the example given, is credited with a thermal value of 62,500 B.T.U. per lb. when burnt to water, but the actual product of combustion is steam, so that this value must be reduced by an amount equivalent to the latent heat of steam, plus a quantity due to the high temperature of the escaping gas.

Where steam is used as an atomizing or pulverizing agent, nearly 1 lb. of steam is, as a rule, used per lb. of fuel burnt. This steam, which only appears as a waste product in the furnace gases, carries away with it a considerable amount of heat, and unless it performs some important duty in the vaporizing of the oil, it appears to be a wasteful, though perhaps useful, method of pulverizing.

Air, on the other hand, is needed to bring about the combustion of the fuel. and although the volume employed for pulverizing is but a small proportion of the total quantity required (about 10 per cent.), it serves to diminish the needful supply of air, and assists combustion instead of retarding it like steam. Air cannot be compressed without the aid of machinery, and, as a result, loss of power in friction of the compressor and cooling of the compressed air; therefore the point to. ascertain is whether, when all losses are taken into account, any saving accrues from the employment of air instead of steam. Experiments conducted by the author seemed to indicate that the difference was very small, if any at all, and as air has not been more generally adopted, except where steam cannot be spared, it is to be presumed that other experimenters have come to a similar conclusion. In one series of experiments an average of 25 cubic feet, or nearly 2 lbs. of free air, were used per lb. of fuel, the pressure of air being maintained at 50 lbs. Lower pressures than 15 lbs. to 20 lbs. did not cause perfect combustion of the fuel, although the air was heated by passage through the flues.

Effect of Moisture on the Thermal Value of Petroleum.—Water is nearly always held in suspension by crude oil and petroleum residues, and the atomization of fuel is generally produced by a jet of steam, consequently water is nearly always present in the furnace, where it exercises a powerful influence on the nature of the combustion. Mr. Orde, in his paper to the Institute of Mechanical Engineers, July, 1902, particularly emphasizes the loss of heat sustained by contamination of the oil with a little water, which he asserts not only abstracts heat and causes a reduction of 13·14 thermal units for each one per cent., but destroys the conditions for perfect combustion, and leads to the elongation of the flame, and consequently the transference of the highest temperature to a point further in the furnace. This has the effect of rendering a portion of the furnace heating surface useless, and, in the case of tubular boilers, of transferring the greatest heat to a point where the boiler material might suffer damage. Professor Vivian Lewes, a well-known authority on petroleum, has repeatedly called attention to the ill effects that a small proportion of water has on the heating qualities of petroleum, and recommends its separation by alternately heating and cooling the fuel in settling vessels prior to use. If water is present in petroleum, the calorific value of the fuel is reduced by the number of heat units which an equivalent amount of oil would have yielded, in addition to the above-mentioned 13·14 B.T.U. per one per cent., so that the actual loss of heat sustained by the presence of 5 per cent. of suspended water in oil is about 1100 B.T.U., or equivalent to an evaporation of over 1 lb. of water.

Steam is naturally the most convenient pulverizing material for liquid fuel, and if it is well superheated before admission to the burner, the negative value of the moisture is reduced as much as possible; but some authorities maintain that it performs a larger duty, and produces a result somewhat similar to the "cracking" process employed in the refining of petroleum. When the steam to a burner is replaced by air at a pressure of about 60 lbs. per square inch, an immediate change is observed in the colour and shape of the flame, for it becomes shorter, and presents a dazzling white appearance, particularly noticeable when two furnaces are compared side by side, using steam and air respectively. When the air is cold, pulverization is accomplished, but vaporization does not immediately occur, for many of the minute particles of oil are driven forwards and outwards, and burn separately on the outer edges of the main flame; but on heating the air to a temperature of about 500° Fahr. before delivery to the injector, the burning particles disappear, and vaporization is brought about at an earlier stage. The main fact to remember in designing a liquid-fuel furnace, is that steam pulverization delays the combustion of the oil to a later period than when moisture is absent, and according to the class of boiler so should the point of maximum temperature be arranged. On marine vessels steam cannot usually be spared, and compressed air, produced either by a small independent condensing engine or an electric motor, is highly desirable, and even in permanent stations a mixture of steam and air or air alone can be used with advantage.

Effect of Impurities on the Thermal Value of Petroleum.—Petroleum often contains impurities, such as oxygen, sulphur, and nitrogen, which, though small in quantity, affect the thermal value of the fuel. Oxygen, when present in a fuel, renders a proportion of the hydrogen, with which it immediately combines, unavailable for heating purposes, and so detracts from the thermal efficiency of the oil.

The common formula for calculating the thermal value of a fuel, as already used on p. 339, is—

$$x = 14{,}500\,C + 62{,}500\,H$$

When oxygen is present in the fuel, the formula is—

$$x = 14{,}500\,C + 62{,}500\left(H - \frac{O}{8}\right)$$

where x = thermal value of the fuel in B.T.U. C = carbon, H = hydrogen, O = oxygen.

Professor Lewes gives a formula which may be used for calculating the evaporative power of petroleum when moisture and oxygen are present—

$$x = \frac{C \times 8{\cdot}080 + \left[\left(H - \frac{O}{8}\right)28{\cdot}780\right] - H_2O \times 600}{536{\cdot}5 \times 100}$$

where C = carbon, H = hydrogen, O = oxygen, H_2O = water, x = lbs. of water evaporated per pound of fuel. (Percentages of oxygen and water must be used.) Sulphur in a similar manner extracts oxygen from the air, and produces sulphur dioxide, which escapes with the ordinary products of combustion; but its formation at too early a period might retard combustion, and transfer the point of maximum heat further into the furnace. Nitrogen would produce no change in the furnace, and only partake of the form of an inactive diluent, as it neither supports combustion nor interferes with the final production of water and carbon dioxide.

Evaporative Efficiency of Oil Fuel in Practice.—The calculated efficiencies of petroleum from analyses are uncertain; the determination of the calorific value of petroleum in a calorimeter, whilst accurately fixing the number of heat units liberated, does not give any idea of the manner in which combustion would occur in practice, and it is only by an actual demonstration in a boiler, and a measurement of the water evaporated, that accurate information can be obtained. The first two methods are useful for the purpose of comparing the value of fuels, and ascertaining the percentages of impurities, moisture, etc., which would not be appreciated when burnt beneath a boiler, for a low efficiency that might be due to contamination with substances that give rise to absorption of heat, could easily be mistaken for some defective feature in the furnace of the boiler.

In the best water-tube boilers, during special tests and under the immediate supervision of experienced engineers, an evaporation of 18 lbs. of water per pound of fuel has been reported, which is equivalent to the conversion of about 80 per cent. of the thermal value of the fuel into steam, as compared with a maximum of 70 per cent. in the case of coal of good quality. In common practice the evaporative performance does not exceed 16 lbs. of water from and at 212° Fahr., compared with good coal, which evaporates only about 9 lbs., 73 per cent. of the fuel in the case of oil, and 60 per cent. in the case of coal being converted into useful work. Some authorities maintain that the theoretical evaporative power of astatki or residuum does not exceed 20 lbs. of water, in which case a still greater proportion of the possible thermal units are converted into work.

On the Russian oil fields low evaporative boilers are in use, and few economizing contrivances are attached, so that the local consumption of fuel works out to anything between 11·5 lbs. and 12·5 lbs. of water per pound of fuel, from water at 62° Fahr. to steam at 60 lbs. pressure, which is equal to 13·7 to 14·9 lbs. of water from and at 212° Fahr. An average of a number of tests showed that about 5 per cent. of the steam generated was used by the burners for atomizing the petroleum; therefore, if an evaporation of 35 lbs. of water* per hour is assumed to be equivalent to one horse-power, then one 45 nominal horse-power boiler evaporating 3000 lbs. of water per hour (about 2700 vedros per day), develops $\frac{3000 - 5 \text{ per cent.}}{35}$, or about 81 horse-power. The combustion of $\frac{35}{12{\cdot}5} = 2{\cdot}8$ lbs. of oil fuel per hour produces, under the bad conditions prevailing on the oil fields, the equivalent of one horse-power.

It follows that on the oil fields only 62 to 67¾ per cent. of the available heat units are directed to useful work in the boilers, the remainder being lost in imperfect combustion following careless adjustment of the steam and oil, and other defects inseparable from the rough conditions, such as use of bad water, that necessitates blowing off periodically, and leads to the formation of an incrustation on the furnace tubes, etc.

The foregoing figures give the efficiencies of the boilers, but the greatest losses take place in the distribution of the steam, which losses, of course, vary

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* A modern superheat, condensing	steam-engine	consumes	10	lbs. of	water	per H.P.	per hour
An ordinary „	„	„	14 to 16	„	„	„	„
A high-class non-condensing	„	„	20 to 23	„	„	„	„
A common „	„	„	25 to 30	„	„	„	„

enormously on different properties. There are losses through friction and condensation in long steam lines, the amount being dependent upon the dimensions of the main, and the quality of the non-conductive covering; losses through leakages, drain-cocks, inefficiency of steam-engines through irregular lubrication and careless packing of glands; in fact, there are innumerable losses on an oil property that can never be quite avoided. The engines, pumps, and machinery are often allowed to work in a bad state of repair, and the intermittent action of the bailing engines, which become cooled between successive runs, conduces to much condensation in the cylinders, and makes it necessary to leave the drain-cocks open for water to escape. All imperfections combine to lower the efficiency, and the consumption of fuel is estimated to amount to 5¼ lbs. per horse-power per hour on a moderately well-planned property, but increases to 6 and 8 lbs. per horse-power per hour on badly designed plots, where the distribution is not carefully arranged. From 2½ lbs. to 5 lbs. of fuel per horse-power per hour are, therefore, lost in the distribution and employment of steam on an oil property, so that really less than 30 per cent. of the theoretical heat value of the fuel is profitably employed.

Types of Liquid-fuel Burners.—There are hundreds of patent liquid-fuel burners in the market, and a journal devoted to petroleum stated that since the Texas craze, several patents a day were filed in the United States for burners alone. Burners may be classified into three types, which Mr. Orde describes as follows:—

(1) Mechanical sprays, in which the liquid fuel is forced under pressure through nozzles made of such a form as to break it up into a fine spray, and thus render it inflammable.

(2) Spray burners, where the liquid fuel is held in suspension, and driven into the furnace by means of a jet of steam or compressed air.

(3) Vapour burners, in which the liquid fuel is volatilized, and the vapour admitted to the furnace.

Mechanical sprays rely upon pressure and passage through a fine orifice to induce a finely divided discharge of oil, but it is very difficult to design an apparatus which will perform this duty on a viscous material like residuum oil.

Spray burners are by far the most popular variety, as the oil is simply expelled from the nozzle, and converted into a fine spray by the action of a jet of steam or compressed air, or both, preferably heated to a high temperature.

Vapour burners are rarely used, and it is difficult to imagine where compensatory benefits are to be derived from the expenditure of so much extra capital. The oil is vaporized in a small gasifier, from whence it is led to the burners of the boiler, but, beyond the convenience of burning gas, no great advantage can accrue.

Mechanical-spray burners, if brought to a state of perfection in a simple form, should attract attention, but at present spray burners are entirely in public favour. The main points to be secured in a burner are to obtain a maximum spraying effect with a minimum expenditure of steam or air, and the attainment of a maximum temperature at the most desirable position in the combustion chamber.

In the Baku oil fields, there must be nearly two thousand steam boilers in use, every one of which is fed by liquid fuel; but in very few cases are refractory furnaces used, and in all but a few instances a simple spray burner is employed, manufactured by local firms; nevertheless, the evaporative efficiency is very fair, considering the bad conditions under which the boilers work (see p. 343). The locally employed burner consists simply of a gun-metal fitting, provided with an internal circular passage, through which oil is led, and an outer annular orifice surrounding this, whereby steam is conducted, both passages communicating with inlets supplied with admission cocks to regulate the supplies of steam and oil. The inside tube, through the centre of which the oil flows, can be made to approach or recede from a tapered mouth given to the interior of the outer casing, thereby producing an annular orifice which can be adjusted to supply the correct amount of steam or air needed for efficient pulverization. A simpler atomizer than this could not be designed; but, nevertheless, it performs its duty well, and is as suitable for the class of boilers in common use as any of the complicated patent burners in the market.

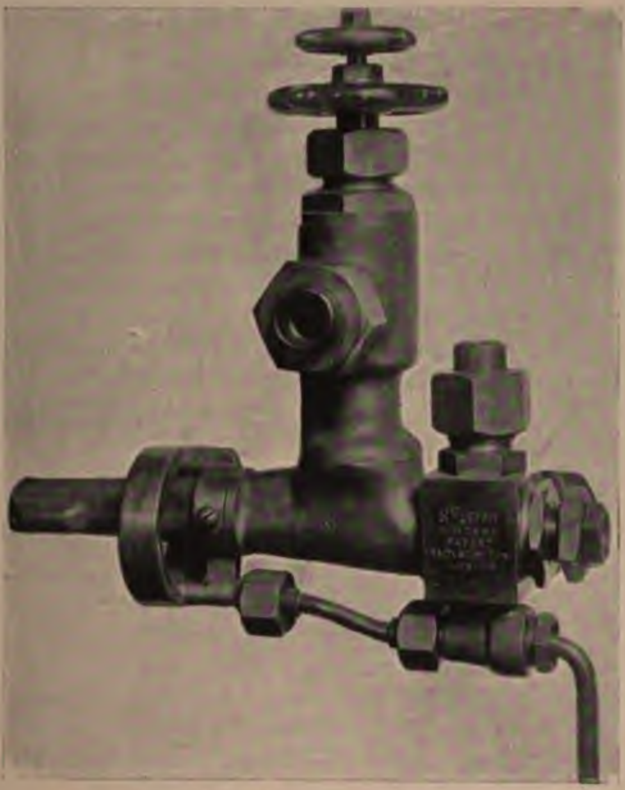

Fig. 83.—Holden's Patent Liquid-fuel Burner.

Some tests were made in the Baku oil fields with the well-known Holden burner, which, in England, has met with much success; but in Baku no greater evaporative efficiency was obtained, notwithstanding the high temperature of the flame. The Holden burner (Fig. 83) has, in addition to a jet of steam which projects the oil into the combustion chamber in a pulverized state, an internal air supply, provided to promote combustion, and an independent external series of fine jets, which are directed on to the flame, the object of the latter being to induce a fierce current of air, which assists in producing rapid and complete combustion. This combination causes the exceedingly high furnace temperature so necessary, apparently, in tubular types of boilers; but in the common Lancashire boiler there is not the same need for an intense initial temperature to complete combustion, owing to the absence of confined spaces such as tubular boilers possess, and an equal evaporative performance seems to result from a slower combustion, where, of course, there is not the same strain on the boiler as where fierce furnace temperatures are produced.

The manner of burning liquid fuel appears to need modification in different classes of boilers, for the burner which gives the best evaporative efficiencies in one class of boiler is often an absolute failure in another. Quantity of heat rather than temperature of combustion is to be aimed at, although experiments seem to indicate that complete combustion, in some types of boilers, can only be promoted by a fierce furnace temperature. In locomotive boilers and water-tube boilers investigations demonstrate that complete combustion of liquid fuel can only be attained by exceedingly high furnace temperatures, necessitating the employment in all cases of fire-brick refractory furnaces; but this, in its turn, seems to point to the need for a specially designed boiler to secure the best advantages from liquid fuel. Up till now it has been the aim of most experimenters to find the best apparatus for burning liquid fuel that can be adapted to boilers in use with solid fuel, and few experiments seem to have been made in the form of boilers.

Spray burners partake of innumerable designs, and use as a pulverizing agent steam, air, or a mixture of the two; but the aim of most has been to obtain an efficient atomization of the particles of petroleum, and thus permit the fuel to be readily consumed. Most burners produce a circular jet, that radiates outwards from the extremity of the nozzle; but others produce a flat flame; and again others are made, by means of a spiral, to impart to the oil and steam a rotary motion, which produces a centrifugal action on escape into the furnace.

It is generally admitted that the air or steam employed for pulverizing in a liquid-fuel burner should be well heated before admission to the burner, as the heat induces a more perfect combustion by vaporizing the finely divided particles of petroleum before ignition occurs.

Liquid-fuel burners use anything from 3 to 12 per cent. of the steam generated, but a good efficient burner will atomize the fuel with an expenditure of 5 per cent. of the steam raised. The simple burners used in the Baku oil fields consume from 5 to 6 per cent. of the steam generated; but the somewhat light crude oils (sp. gr. 0·875 to 0·885) do not require such efficient pulverization as residuum (astatki), and where the latter fuel is used, no doubt more steam would be needed. From $\frac{3}{4}$ lb. to $\frac{4}{5}$ lb. of steam are therefore consumed per lb. of fuel burnt, under fairly good conditions, in the Baku oil fields.

Advantages attending the Use of Liquid Fuel.—The advantages secured by the employment of liquid fuel are both numerous and great, and an engineer who has once been associated with liquid fuel would very reluctantly return to solid fuel. People unacquainted with the general use of petroleum refuse imagine that there is always a serious risk from fire; but, except on the oil fields, where crude oil is habitually employed, there is absolutely no danger, and a person would find that he would have some difficulty in igniting residuum, and discover that lighted matches or wood would at once be extinguished by submersion in a tank of fuel.

The following table has been prepared for the purpose of showing the relative values of petroleum and coal:—

TABLE XXVII.

COMPARISON OF OIL AND COAL FUEL.

	Petroleum.	Coal of average quality.
Weight per cubic foot	54 lbs. (1·5 poods)	79·4 lbs. solid, 49 lbs. loose lumps
Volume per lb.	0·0185 cubic foot	0·0126 cubic foot solid, 0·0204 cubic foot loose
Percentage of carbon	86 per cent.	80 per cent.
Hydrogen	13–14 per cent.	5 „
Impurities	1–1·2 „	15 „ (ash)
Consumption of oxygen per lb.	3·41 lbs.	2·5 lbs.
„ air per lb.	14·82 lbs. (194·7 cubic feet)	10·95 lbs. (144·1 cubic feet)
Weight of CO_2 produced by 1 lb.	3·14 lbs.	2·94 lbs.
„ H_2O „ „	1·26 lbs.	0·47 lbs.
Theoretical evaporative power per lb.	22 lbs. water	14 lbs. water
Actual „ „ (normal)	13–16 lbs. water	8–10 lbs. water
Units of heat developed by 1 lb.	18,000–21,000 B.T.U.	13,000–15,000 B.T.U.
„ „ „	10,000–12,000 calories	7400–8500 calories

Amongst the many advantages secured by the use of liquid fuel are the following, many of which will appeal strongly to all users of steam power:—

(1) A reduction of 40 per cent. in the weight of fuel.
(2) „ „ 35 „ „ bulk „
(3) „ „ 75 „ „ number of stokers required.
(4) Rapidity of filling storage with liquid fuel.
(5) „ lighting fire and raising steam.
(6) „ extinguishing fire.
(7) Ease with which the flame can be delicately adjusted to suit the demand for steam.
(8) Entire absence of smoke.
(9) Perfect cleanliness in its use—no coal-dust nor dirt.
(10) Perfect combustion in furnace; no clinker, cinder, nor ashes to clear from furnace, remove from boiler-house, and find storage for, or cart away to a distance.

Petroleum Gas.—The subject of fuel should not be dismissed without a short description of the methods used for the conversion of petroleum into gaseous products for subsequent use with gas-engines or other plant. Gas is a power that daily increases in importance, and is likely to be brought still further to the foreground during the next few years; indeed, gas can claim so many advantages over other sources of energy, that nothing can prevent the extension of its use. Gas can be generated simply, its storage is simple, its distribution is not attended by great expense or danger like electricity, its value does not materially deteriorate by long standing in reservoirs, it can be utilized for heating furnaces, stoves, etc., it can be employed for gas-engines, and, with slight purification, can be used for lighting purposes. Gas plants are peculiarly adapted to electrical generating stations, compressed-air installations, large pumping centres, or anywhere where large power is needed for driving special machinery; therefore, it is strange that so little use has been made of gas on the oil fields, less than half a dozen plants being in operation in the Baku district.

One of the best-known systems of producing gas from oil is the Pintsch apparatus, where a slow stream of petroleum is fed into a series of cast-iron D-shaped retorts, heated to a bright-red heat by a furnace beneath. The entrance of the oil is effected by passage through a syphon, which prevents the gases from escaping backwards, and the vapours of the oil, which are completely gasified by the time the third retort is reached, are conducted into a hydraulic main, where the tar separates, and leaves a gas which passes on to reservoirs where it is stored. The gas leaves the water at a pressure of 3 to 4 inches (80 mm. to 100 mm.), and if it is only needed to drive gas-engines or heat furnaces, no additional purification is necessary; but, if required for lighting, the impurities must be abstracted by passing over chemicals that absorb the injurious compounds, and it must be further well washed. Messrs. Nobel Bros. have had a Pintsch gas-producing plant in continuous work for three years at their Saboontchy generating station, with excellent results, as the following particulars, for which the author is indebted to the courtesy of Messrs. Nobel, will show:—

TABLE XXVIII.

PRODUCTS OBTAINED FROM THE PINTSCH GAS GENERATING PLANT.

(When used with petroleum.)

Description of oil used.	Gas.		Waste products.			Fuel. Crude oil in all cases.	
	Cubic meters per 100 kilogs.	Cubic feet per lb. of oil.	Heavy tar.	Light tar.	Coke.	Kilogs. per 100 kilogs. of oil.	Pounds per 1000 cubic feet of gas.
Crude oil (sp. gr. 0·879)	52·80	8·50	19·0	18·9	3·0	59·2	70·0
Solar oil (sp. gr. 0·892)	54·90	8·80	19·6	20·4	2·25	76·15	86·7
Astatki (sp. gr. 0·904)	52·90	8·47	13·4	23·9	3·80	71·70	84·6

One complete retort of three vessels, arranged one above another, yields 7·9 cubic metres, or 279 cubic feet of gas per hour, which is equivalent to from 25 to 27 horse-power when operating a gas-engine; but there is a waste product of tar which finds a ready local sale for asphalt purposes. The Pintsch gas plant has been tested with crude oil, solar oil, and astatki, and the above table gives the results, the fuel being in all cases crude oil. It will be observed that, although the quantity of gas varies very little in each case, the consumption of fuel is very much larger when solar oil or astatki is used.

There are other producer plants in the Baku oil fields which have given general satisfaction, especially one known as the Pickering process, that owes much of its value to simplicity, neatness, and compactness of construction. The Pickering plant consists of a circle of six or eight vertical tubes, in the centre of which is placed the furnace for heating them up. A rod is suspended in the middle of each tube, fitted with a series of metallic conical discs with their point upwards, upon which the oil drops and becomes converted into gas before the lower discs are reached. The oil, admitted from the top by a syphon, descends very slowly over the discs, and the gas produced is conducted first into the hydraulic main, where the tar separates, and then to the gas-holders. The method of cleaning calls for special notice; for, whereas in the Pintsch plant the retorts have to be removed frequently (once every four months), and replaced by new ones, the Pickering retort can be rendered equal to new by simply opening a manhole door at the bottom and top of the tube, and allowing a current of air to circulate through the vessel, when the whole of the coke is burnt and the retort can be restarted.* A single tube in a furnace produces from 300 to 400 cubic feet of gas per hour, and 1 lb. of oil gives about 8¼ cubic feet of gas. Therefore, a battery of six retorts, fed by a single furnace, will yield, allowing one always free for cleaning, 1500 to 2000 cubic feet of gas per hour, or, approximately, 150 horse-power.

Another type of plant for generating oil gas has been erected at the Caspian and Black Sea Society's electrical power station at Zabrat. The installation is of German origin, and, whilst producing a gas at a low expenditure of fuel, the quality varies considerably, and there have been constant delays through defects in the plant. The table below gives the composition of the gases derived from the three plants when using crude oil, and the calorific value of the gas, obtained from actual experiment—

* The life of a retort is said to be a year and a half.

TABLE XXIX.

PERCENT POSITION OF GASES FROM DIFFERENT TYPES OF PRODUCER PLANTS USING CRUDE OIL.

System.	Methane (CH_4).	Hydrogen (H).	Acetylene (C_2H_2).	Carbon monoxide (CO).	Carbon dioxide (CO_2).	Oxygen (O).	Sp. gr.	Calorific value (actual experiment).	
								Calories.	B.T.U.
Pintsch	43·2 $+5\ ^\circ/_\circ\ C_2H_4$	10·2	34·0	0·5	0·5	0·4	0·777	13,570	23,883
Pickering	56·0	25·5	17·0	0·6	0·2	0·2	0·576	8932	15,720
German	47·0–48·5 $+ 5\ ^\circ/_\circ$ N	22·5–29·2	11·2–25·2	1·3–2·6	1·2–2·0	0·4	0·538 to 0·670	8719 to 10,570	15,345 to 18,719

The next table gives the actual consumption of oil by the three systems, inclusive of fuel (in all cases crude oil), to produce 1000 cubic feet of petroleum gas.

TABLE XXX.

POUNDS OF OIL REQUIRED TO PRODUCE 1000 CUBIC FEET OF GAS IN DIFFERENT PROCESSES.

	Pintsch system.			Pickering system.	German system.
	Crude oil.	Solar oil.	Astatki.	Crude oil.	Crude oil.
Pounds of oil required to produce 1000 cubic feet of gas, inclusive of fuel . . .	187·6	200·3	202·6	144·0	101·0

The Pintsch gas has the highest calorific value, and is absorbed by the gas-engines at the rate of 10 to 11 cubic feet per horse-power per hour, whilst that from the other plants necessitates the combustion of about 12½ cubic feet of gas per hour per horse-power; but the Pickering gas plant is much cheaper to erect, its maintenance is next to nothing, and, when all features are considered, the cost of the gas is little more than half that from the other processes. The actual consumption of oil per brake horse-power in the three systems is—

Pintsch method	1·97 lbs.	crude oil per H.P. per hour
Pickering „	1·80 „	„ „ „
German „	1·26 „	„ „ „

CHAPTER XIV.

FIRES ON THE OIL FIELDS.

Causes of Fire, and Methods of Preventing and Extinguishing it.—*Overheating of Top Bailing Pulley Bearings.*—The ordinary careless manner of lubrication responsible for many fires—Description of automatic lubricators. *Faulty Electric Light Fittings and Short-circuiting.*—Any defect or accident that leads to fusing or sparking may originate a fire—Concrete example of the firing of a fountain of Nobel Bros'—Other probable examples. *Sparks produced by striking of Bailer against Ironwork.*—These sparks most frequently unable to fire the gas, but do so occasionally—Definite examples—Provisions to avoid this risk. *Overheated Bailing-drum Brakes and Friction-wheel Blocks.*—Conditions when there is danger—Method of meeting it. *Sparks by Stones ejected from Fountains.*—Chances of ignition remote—Precautions where bailing resorted to to produce flow. *Incautious Smoking and the use of Matches.*—Extent of danger—Regulations and precautions. *Incendiarism.*—Due to Eastern spirit of revenge. *Extension of Fire.*—Primitive crude-oil stoves to be found in kitchens responsible for fires—Danger from iron boiler-chimneys and chimneys of dwelling-houses—Boiler-houses taking fire.

Fire-proof Derricks.—Iron derricks as yet only experimental, and probably of limited application—Iron engine-sheds of more value—Fire-proof sheathing for derricks.

Sprinklers.—Importance of prompt measures—Usual arrangement of sprinkler.

Steam Jets.—Description of arrangements usually adopted.

General Fire Service.—Disposition of fire mains—Complications and danger from not having special pumps for fire purposes—Important points of a fire-pump—Storage of water—Description of hose to be employed, and its preservation—What should be done on the outbreak of a fire—Notes of some remarkable fires.

Fountains on Fire.—Precautions to be taken on a fountain beginning to spout—Devices for extinguishing burning fountains—No arrangement of much avail in Russian wells.

CHAPTER XIV.

FIRES ON THE OIL FIELDS.

Causes of Fire and Methods of preventing and extinguishing it.—One of the most terrible occurrences on an oil field is an outbreak of fire, which will, in the space of a few hours, if allowed to spread unchecked, devastate acre after acre, and wipe away hundreds of derricks, thousands of pounds' worth of machinery, and render hundreds of employees homeless. Directly the fire-whistles or syrens are sounded, every one is on the alert, and many anxious faces are turned to observe the direction of the fire and the quarter of the wind, for upon the latter depends the safety or the danger of the property. No questions are needed to learn the whereabouts of the conflagration, for in the day-time a colossal cloud of black smoke will be observed rising, totally obscuring the light wherever it floats, and at night a lurid glare, an illuminated sky, thousands of sparks, and floating pieces of burning wood will disclose its situation.

On an outbreak of fire all companies in the vicinity must warn their neighbours and employees by blowing their steam whistles and syrens intermittently, *i.e.*, by pausing a few seconds between successive blasts, and persons are prohibited from blowing signals in this manner except in case of fire. Owing to the suddenness of an alarm, and the extreme rapidity with which a fire on an oil property spreads, involving all surrounding property, it is very difficult, in most cases, to trace the cause of many of the destructive conflagrations which periodically occur; but much authentic information has been obtained which is of value in taking preventive measures.

Fires originate from the following causes:—

(1) Overheating of top bailing pulley bearings.

(2) Faulty electric light fittings and short-circuiting.

(3) Sparks produced by striking of bailer against ironwork.

(4) Overheated bailing-drum brakes and friction-wheel blocks.

(5) Sparks produced by stones ejected by fountains striking iron fittings or tools.

(6) Incautious smoking or use of matches.

(7) Incendiarism.

(8) Extension of fire from burning dwelling-houses, sparks from chimneys and boiler-houses.

Each of the causes enumerated will be separately considered, and mention made of the most obvious and usual precautions adopted to secure safety; but, of course, the real danger lies in the speed with which a fire extends under the influence of a light breeze. The heat emitted from a burning derrick saturated with inflammable petroleum (which blazes the more fiercely because of the blast due to the chimney-like form of the derrick) is intense, and besides being itself a source of considerable danger to adjacent property, it is not less so to far-removed plots, on account of the fierce uprush of heated air carrying lighted particles and burning fragments of timber to a great height, where they drift in an ignited condition to remote parts, and to open ambars of oil.

(1) *Overheating of Top Bailing-pulley Bearings.*—The most common form of pulley runs in cast-iron bearings fitted with an open receptacle for oiling, and relies to a large extent upon the oil it receives from the wet rope passing over the pulley which indeed keeps the upper part of the derrick saturated with oil. It is a careless practice to rely upon lubrication obtained in this manner, and where this simple form is employed care should be taken to inspect the bearings, and to clean and oil them twice daily, as they are very liable to get clogged with dirt, run hot, and cause a fire. Self-oiling bearings may now be purchased at a slightly increased cost, which contain in a vessel sufficient oil to lubricate the bearing for a week, the oil being deposited on the shaft by a collar or piece of chain which revolves on the spindle and passes through the lubricant. The top is enclosed by a tight-fitting cap which prevents the admission of sand or dirt, and if those of simple construction and good workmanship are purchased they should last many months with only a weekly inspection. A very inexpensive type used by a number of firms, and which can be highly recommended, consists of a wooden base-block about 12 inches wide bored out a little larger than the pulley-shaft, into which white metal is run to form a bearing surface. Two grooves are left to act as vessels for storing lubricants, and the position of the liner in the wooden blocks is secured by allowing the metal to run into several holes bored in the wood. A plain wooden cap fitted with a lubricator completes the device, which is simple, safe, easily fixed, and very effective. Many fires originate from overheated bearings on the top pulley; but if the outbreak is observed early, and a fire-hose is available of sufficient force to reach the top, it may easily be extinguished, as the fire rarely shows any inclination to descend, and the chief danger lies in the probable ignition of ascending gases, or the woodwork at the mouth of the well, through sparks falling from the fire at the derrick top. Such fires are often put out by plucky workmen, who ascend the derrick and suffocate the glowing timbers with their coats. Fig. 84 shows a safety, self-oiling bearing manufactured by the Votan Co., Baku.

(2) *Faulty Electric Light Fittings and Short-circuiting.*—Electric light fittings are often responsible for fires, either through defects, or accidents in their use.

An oil-soaked board may take fire through faulty insulation, and cause an ignition of gas; or a wire may fuse and lead to a similar disaster. It has been remarked that a large number of fires have started in the early hours of the evening, after the dynamos have been put into operation, and this fact suggests that they have originated in some manner from the electrical arrangements. An accident at a well may produce a fracture of the electric wires at night, and so cause a fire; or a strong fountain suddenly blowing before the current can be switched off may smash the lamp-glasses or break the wires, and cause an explosion. Several fountains have taken fire from this cause, an exceptionally strong outburst of stones and gas smashing up the derrick and breaking the electric wires. In August, 1902, a fountain of Nobel Bros' commenced to spout very strongly, and an employee, hoping to avert a fire by extinguishing the light, cut the electric wires, and thereby caused the very accident he sought to prevent, for an explosion followed, from the effect of which he succumbed, and several other men were severely injured. This recent accident caused a special order to be given with reference to electrical attachments.

Fountains rarely become ignited in the daytime, except from other fires, so that it seems very probable that the electrical connections are to blame for the disasters; and of the two fountain fires in Saboontchy in 1902, one belonging to Tumaieff and the other to Musa Nagieff, this was apparently the cause.

(3) *Sparks produced by striking of Bailer against Ironwork.*—A spark caused by the striking of one iron body against another, in ninety-nine cases out of a hundred will not explode a mixture of petroleum gas and air, but it may on the hundredth occasion. The author has frequently seen brilliant sparks at the mouth of the most gaseous wells caused by the striking of the bailer against the side of the tube during its entry to the well, without any ill result, and he has had under his immediate notice one case in which the gas was very small in quantity, but which instantly took fire as the bailer struck the side of the top tube. In the latter example the fire was extinguished by placing sheets of felt over the mouth of the casing, as there was, fortunately, no woodwork in the immediate vicinity to take fire. It is difficult to account for the ignition of gas in one case and not in another; but it may perhaps be explained by the presence of a larger proportion of benzine or highly inflammable gases than usual, or to the presence of the correct proportion of air and gas to form a mixture inflammable enough to take fire from the heat of a dislodged particle of heated iron. There are other authentic instances of fires originating in this manner, and every one recognizes that there is a danger from this cause, and some provision is made by most companies to remove the risk. Copper rings may be made to encircle the rim of the surface tube, against which the bailer may strike harmlessly; or a large conical bell-mouthed ring may be riveted to the upper tube to guide the bailer straight into the well. A conical wooden

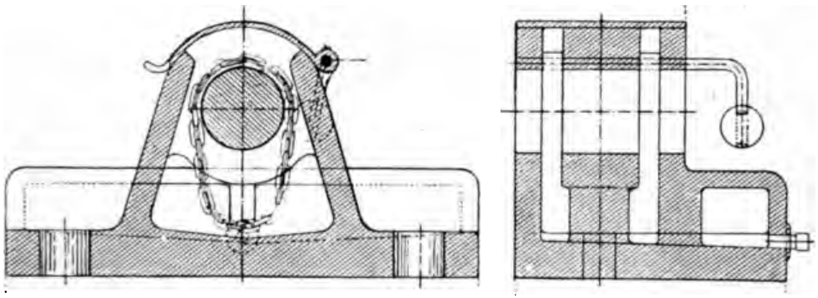

Fig. 84.—Safety Pedestal for Bailing Pulley.
(Made by Votan Co., Baku.)

mouthpiece, made in two halves, and bolted by two ¾-inch bolts, may be attached to the surface tube, the smaller and lower end of the cone being slightly less in diameter than the size of the lining tubes. Wooden guide-blocks of this description, although somewhat cumbersome, form a cheap and perfect safeguard, and are not such a temptation for theft as the copper rings which frequently disappear mysteriously.

Another way in which the gases may ignite is by the concussion of the spindle of the bailer valve against the iron sliding plate upon which the bailer is lowered to discharge its contents, and this danger, like the former, may be entirely removed by replacing the iron slab for a copper or brass one. In Grosny, at least one firm has reduced the risk by passing a small steam jet into the bailing tub, which performs the double purpose of creating a draught and so preventing the collection of gases, and keeping everything inside the tube saturated with moisture.

(4) *Overheated Bailing-drum Brakes and Friction-wheel Blocks.*—Where the bailer is lowered at a high velocity through a great depth before the oil is reached, a considerable strain falls on the brake of the drum, and the timber hardwood blocks of which it is made often become hot enough to ignite, and are therefore a source of danger. Engineers should insist upon water-tubs being fixed in every derrick where the gas is strong and the bailing speed is fast, at a sufficient altitude to cause a constant flow of water by gravitation to the brake-wheel through small tubes regulated by a cock. When the wooden wedge-pieces have become worn by age, or through some other cause do not firmly grip the drum, the slipping is liable to heat up the blocks to a dangerous degree.

A little resin or common chalk judiciously applied will often stop slipping which has started through oil finding its way on to the friction-blocks.

(5) *Sparks by Stones ejected from Fountains.*—A fountain often commences to play before the boring rods and tools are removed from the derrick, and there is always the danger of a fire originating from a stone striking the ironwork with force and causing the confined gas to explode. Here, also, the chances of ignition are remote, and whilst a hundred wells may spout violently and fling out numerous stones with force, only one may take fire from this cause. In a spouting well, where bailing is periodically conducted to induce a flow, all iron or steel work in the path of the fountain should be removed, and any material with which the bailer is likely to come into contact should be wood, copper, or brass. The fountain-blocks upon which the full force of the fountain impinges should be made of cast-iron or wood, but not of wrought-iron.

(6) *Incautious Smoking and Use of Matches.*—Nearly all Russians, and particularly the Caucasian races, partake of the fragrant weed, and the regulations for Russian industries differ from those in use in England, in that employees are permitted to smoke during their work; in fact, it is an unwritten law, which cannot be broken, that labourers are allowed frequent intervals for rest and smoking. The habit is, of course, strictly prohibited on the oil properties in the vicinity of derricks and ambars, and notice-boards are erected at frequent intervals to warn employees; but this does not prevent the men from retiring to secluded spots where they may enjoy their cigarette undisturbed and unobserved.

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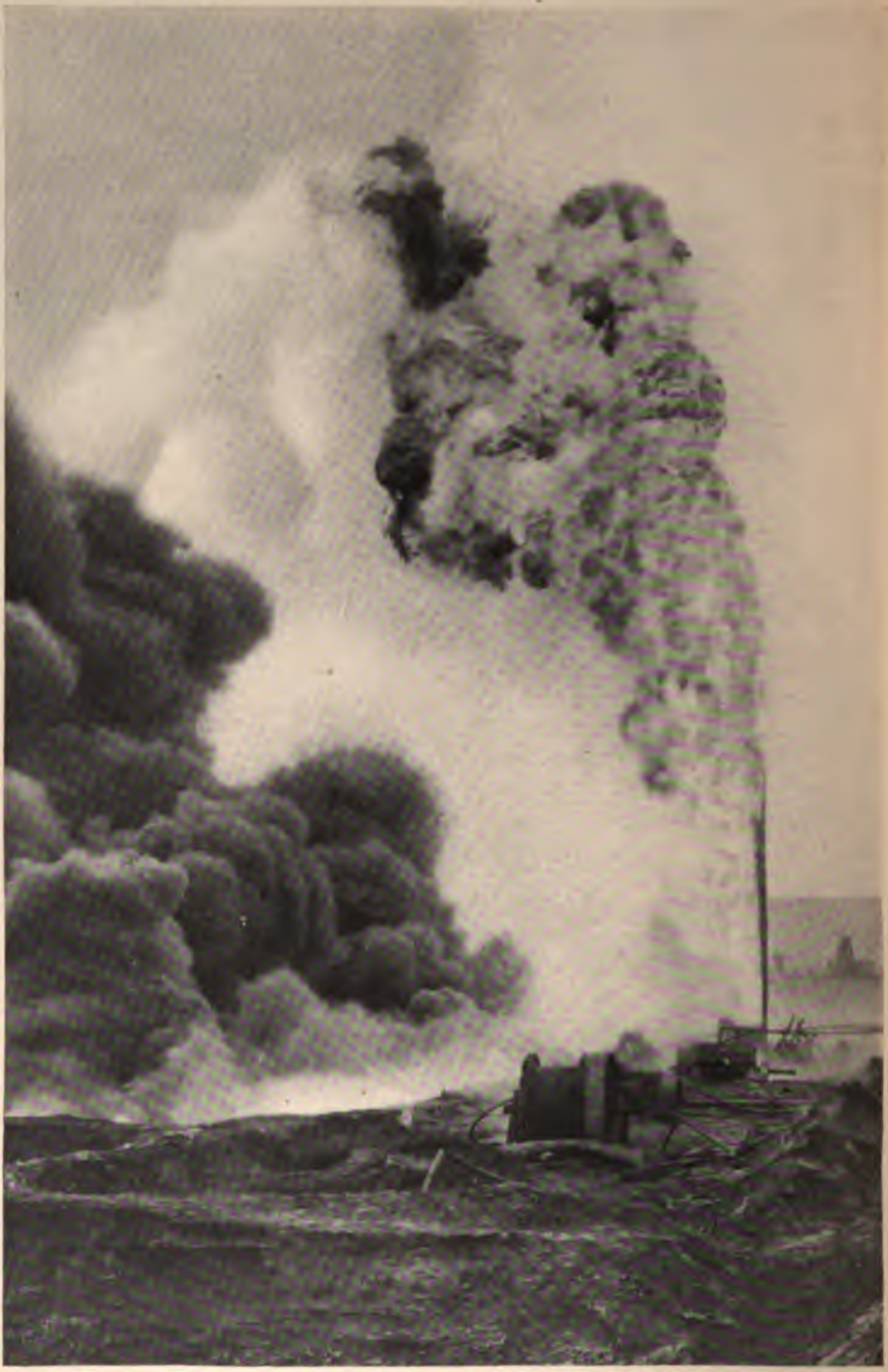

Fig. 85.—A Burning Fountain on Plot 29, Bibi-Eibat.
(No. 4 well, Schibaieff Petroleum Co. 6 inches diameter only.)

The custom is so far recognized by some companies that they have erected for their employees small smoke-boxes out of danger on the plot, where the men may occasionally retire and have their smoke. As the men will smoke at any cost, and no regulations will prevent them, it is better to acknowledge the custom, and take such precautions as will prevent careless smoking. If a lighted match or glowing cigarette were plunged into crude oil it would, in most cases, be instantly extinguished without causing ignition of the oil; but if the glowing part were to remain in contact with the oil for sufficient time to cause a rise of temperature and evolution of gas, ignition would ensue.

If crude oil, coming direct from the well, has not been exposed for a long time to the air, it gives off gas freely at ordinary temperatures, and will much more readily ignite than oil which has been stored for some days, and deprived of some of the most volatile and inflammable constituents. Gas will readily explode on the application of a glowing match or cigarette, and it is therefore quite necessary to enforce the most strict regulations in regard to smoking on an oil property, except in defined situations removed from all danger. "Familiarity breeds contempt," and nowhere is this better exemplified than on the oil fields, where the men are surrounded by, and daily move amongst the most inflammable materials, and where, unless the rules are enforced, they will be found smoking at the mouth of the well, at the imminent risk of their own and many other people's lives.

(7) *Incendiarism.*—Incendiarism has in a great many instances been the cause of disastrous fires, judging by the number of conflagrations that have originated in old and disused derricks, and on the borders of public roads. There are also many examples of determined attempts to fire properties, which have only failed through the timely arrival of an employee; other attempts have also been detected by the discovery of a quantity of oil-soaked waste and other material in a disused derrick, the materials having evidently failed to burn. Threatening letters are frequently received by managers of oil properties, giving warning of fire; and there is no doubt that the prevalence of incendiarism is due to the Eastern spirit of revenge so easily aroused in an angered or discharged man, an unemployed workman, or a jealous acquaintance.

(8) *Extension of Fire.*—An outbreak of fire may commence from a very small occurrence, from some insignificant accident or oversight, and spread in a few moments so as to envelop acres of ground. Dwelling-houses and workmen's barracks are often the scene of an outbreak of fire, generally due to the careless use of the primitive crude-oil stoves which are invariably used on the oil fields, although prohibited in Baku and large towns. The crude oil is simply run into a cast-iron box arranged in the stove, where it is only partially consumed, and its combustion is attended by volumes of heavy black smoke and lumps of dislodged soot. Unless the cock regulating the oil supply is properly adjusted before the attendant leaves the kitchen, more oil may be run into the box than the stove can consume, the result being that it overflows into the room, and in a few moments it ignites all the inflammable material within its range. The sparks from burning buildings may be carried by the wind to ambars of oil and petroleum-soaked derricks, that in a few minutes become a sheet of flame. Fuel tanks for containing the oil to feed kitchen stoves are often a source of

danger during a fire, for the framework of wood upon which they are generally raised is destroyed, and the burning oil flows along the ground, and if unchecked may reach dangerous situations. Iron boiler chimneys should be forbidden by legislation within the oil districts, and regulations should be enforced to clear away, within a stated period, all those in use. The heated waste products of combustion, often conveying soot from imperfect combustion, meet with the chimney whose sides are chilled by the cold air outside, and this causes an accumulation of soot to collect on the inside which is periodically dislodged by the draught and carried in a red-hot state, by wind, to a considerable distance. A baffle-plate riveted to the summit of the chimney reduces the risk, but does not overcome it. Chimneys of dwelling-houses and kitchens, if situated near oil properties, are just as dangerous, and need much stricter rules to ensure safety. Boiler-houses frequently take fire from a number of causes, but if the provisions are taken which are stated in the chapter on "Steam," there need be little fear of much damage. Perfect isolation from inflammable substances and ambars of oil connected with the property is absolutely essential.

Fire-proof Derricks.—The destruction of an isolated derrick on an oil field would be a very small concern in itself. The chief danger lies in its proximity to many others which also become involved, and in turn transmit the fire to others, so that the construction of a fire-proof derrick would be an almost complete solution of the fire problem. Iron derricks have not yet passed the experimental stage, and it is doubtful whether, in practice, they will become general on account of their great expense, difficulty of erection, and of removal, and other causes. The derrick not only has to be of massive build and strongly braced to resist the heavy work of boring, but the presence of such ironwork would be very dangerous in the case of fountains spouting and ejecting stones. If iron derricks do come into use, they will probably be confined to bailing wells, where all danger of fountains has ceased, and where a light skeleton frame, well braced, would be ample to withstand the work of bailing, and could be transferred to another locality with ease. Engine-sheds may, however, be cheaply and profitably constructed from iron which will very effectively protect the machinery inside; indeed, at a recent fire on the Russian Petroleum and Liquid Fuel Co.'s plot at Bibi-Eibat, the sheathing of such sheds was made red hot, but the machinery and the wooden derrick escaped destruction. The chief danger to iron engine-houses is from falling derrick-poles, which crush the light framework if they fall in that direction. Much attention has been directed during the last few years to covering the wooden skeleton of the derrick and engine-shed with some fire-proof or non-inflammable substance, and numerous materials have been tried for this object, with varying success. A light sheet-iron sheathing was one of the earliest ideas, and it is probable that this is the best form of covering yet invented for the purpose. The whole of the derrick and engine-shed was prepared by attaching parallel laths against which the sheets of iron were nailed with copper, brass, or galvanized iron nails, the edges of the sheets being made to overlap or to fit together, thus :

The sheets should previously be prepared by dipping in boiled oil, and after fixing should be given a coating of "oxide" or some other paint of a preservative nature, to prevent rusting. Other non-inflammable materials employed in the same manner for covering the derricks are specially prepared asbestos boarding, uralite, and a sheathing which is really a deposit of plaster of Paris upon a wooden lattice-work, and is manufactured in Baku. All these compositions are useful and do assist in preventing the spread of a fire, but a practical demonstration of various kinds of non-inflammable materials conducted by the Russian Petroleum and Liquid Fuel Co., in Bibi-Eibat, proved that iron was the most efficient covering to the derrick, and survived the effects of a fire longer than any other coating. Derricks which are covered with these materials will not readily ignite, even if exposed to showers of sparks and pieces of burning wood; but if they are situated near burning substances which give out great heat, the woodwork underneath takes fire, after which the coating is of no avail. When a fire originates in a covered derrick, or when an ambar or a tank of oil takes fire close to it, the non-inflammable material does not help in the least; but it has been observed that one advantage is secured by iron-covered derricks even when burning, viz., that the sheathing tends to keep the woodwork entire until it is nearly completely consumed, and thus considerably reduces the number of sparks and burning pieces which fall around. Covered derricks assist very little on congested areas where all companies do not join and take similar precautions; and it is doubtful whether anything short of iron derricks, or those composed entirely of some non-inflammable material, will deal successfully with the problem.

Sprinklers.—The fire question is not solved by any of the methods yet mentioned, and it is obviously of the utmost importance that a good water service should be available to act in conjunction with other precautionary measures, for prompt action at the very outbreak of a fire may be the means of preventing a fearful conflagration. If derricks are in close proximity to one another, and the outbreak occurs in a well to the windward side of the cluster, no protective covering, water supply, or anything but a change of wind, is likely to save them from destruction, as the intense heat cannot be resisted, and the firemen cannot approach the site on the important side. If, on the other hand, a fire originates in a derrick on the leeward side of a group, adjoining wells may be saved sometimes if a copious supply of water is obtainable, and the escaping gases from the wells are not strong enough to cause an explosion. To prevent the wood from taking fire, sprinklers have, during the last few years, come to the forefront, and, if properly arranged and supplied with an abundance of water at a high pressure, are very useful. The early practice of fixing a conical spray a foot or two above the summit of the derrick is certainly not to be recommended, as in a strong wind the bulk of the water is blown completely to one side, and the attachment entirely fails in its object. The usual arrangement consists of a tube, which runs along the full length of the engine-shed and up to the summit of the derrick, round which it is coiled. All the parts, with the exception of the vertical pipe, are perforated, and during a fire a constant stream of water is forced through and discharged on to the woodwork. The objections to this device are expense, the frequent choking of the tubes and perforations by accumulations of rust and particles of dirt which find their way into the water, and the rapid rusting of the tubes on account of the intense salinity of the water used. Sprinklers have been largely adopted by many firms during the last year (1903), but their presence has not prevented the destruction of a large number of derricks so fitted. Many companies who have a limited sum of money at their disposal for fire purposes prefer to expend it on increasing the efficiency of the general fire service, and keeping large high-pressure pumps ready, and having a number of hoses in convenient spots which can all be concentrated to one point where the danger is greatest.

Steam Jets.—One simple fitting, almost invariably adopted where steam is used to assist in the extinction of fire, is a $1\frac{1}{4}$- to $1\frac{1}{2}$-inch steam-valve, which is placed near the engine, and always opened on the first alarm of fire. The effect of the escaping steam is to saturate the derrick with moisture, and cause a discharge of damp spray to issue from every open space or unprotected spot in the derrick, thus assisting to extinguish lighted particles that approach its vicinity.

Some firms also arrange a series of small perforated tubes round the base of their boring machines, and if the escaping steam does not actually save the machinery from damage, it prevents the woodwork from burning fiercely and causing the fracture of a large part of the ironwork.

General Fire Service.—A carefully planned fire service is of the greatest importance; and an organized staff is also of great value, for everything depends on the manner and speed with which a fire is combated. The fire-line should all be underground, and leave no exposed portions which might be damaged by falls of derrick-poles or parts of machinery; it should be well proportioned for the number of hoses that may be needed at one time. Wrought-iron tubes are generally employed for fire-lines; but they are rapidly corroded by the saline well-waters, and after a few years give endless trouble, and require constant renewals and repairs to keep in order. In laying out a new extensive plot, it is far better to lay as a permanency a 5-inch or 6-inch cast-iron main that will last for many years, give no trouble, and need no repairs, and that will, in the end, repay itself. The fire main should be centrally and conveniently placed, with due consideration to future borings, and should be furnished at frequent intervals with stand-pipes, painted red, to be easily distinguished, and located in positions which can be safely approached when derricks are burning. Stop-valves should be inserted in the main pipe at several points, so that parts of the fire service may be disconnected from the main if a stand-pipe is broken or hoses have to be abandoned without shutting off the water supply.

Many companies do not keep a special form of pump solely for fire purposes or cases of emergency, but they have an arrangement of valves at the pump-station so that the ordinary pumps may have their suctions and deliveries diverted to discharge water into the fire-line. This plan is far from satisfactory, unless most carefully designed and explained by simple instructions, as the complication of valves causes much confusion at the moment of an outbreak of fire; and often further hesitation and delay are occasioned by the absence of responsible persons who are fully acquainted with the connections. A part of the mains so converted into the fire service is often filled with oil, which, in the excitement of the moment, may be pumped into the fire-line; and at one fire the author saw crude oil thrown from a hose owing to this cause, with results that can be imagined. The fire-pump should, wherever possible, be quite distinct, and have a separate suction, and should only be employed for other work in cases of emergency, such as a fountain; for it is advisable, even when a fire is raging on the property, to continue to pump away the oil, and so reduce the risk and damage. The dimensions of the fire-pump must depend upon the size of the property and the maximum number of hoses it is desired to bring into operation at one time; but if sprays are fixed to the derricks also, the quantity of water needed for their supply must be carefully estimated. Duplex pumps are the most suitable class, because a more steady and continuous discharge is maintained than by single pumps; but this is not a matter of importance so long as a full supply of water can be kept up at a pressure of from 120 lbs. to 150 lbs. The pumps must be fitted with gun-metal or non-corroding valves and seatings, cylinder liner, piston rod, and glands to resist the corrosive action of the water pumped from the wells, generally used for fire purposes, registering from 3 per cent. to 12 per cent. of salt; and special precautions must be taken in the fixing to ensure the suction being perfectly air-tight and always primed and ready for instant use. The fire pump or pumps

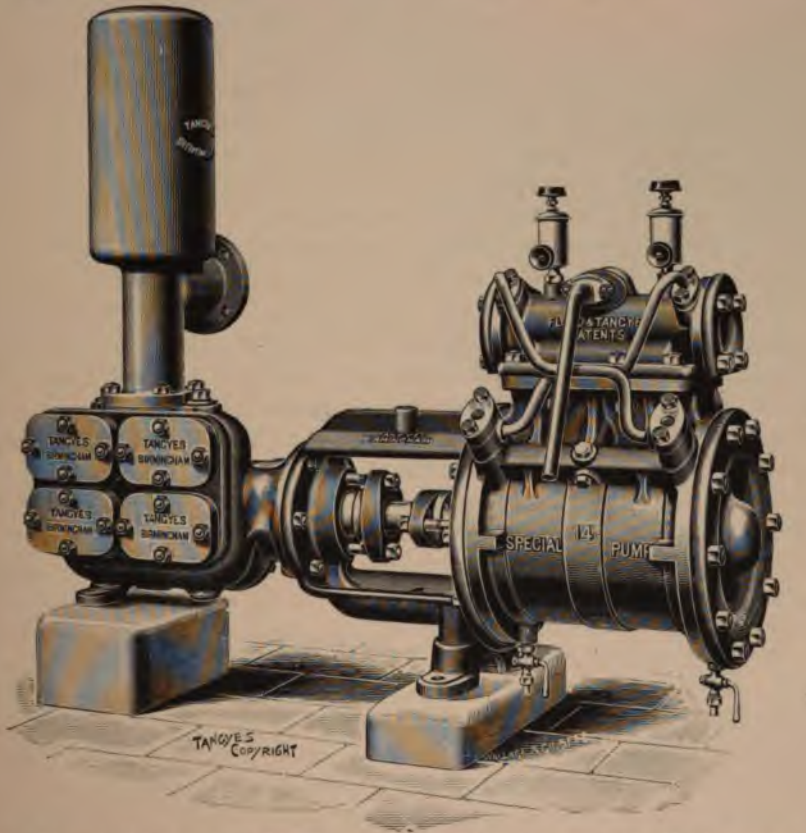

Fig. 86.—A "Tangye" Steam Pump, very largely used for Oil Pumping and Fire Service Purposes.
(Size 14 inches × 7 inches × 24 inches.)

ed as near to the boiler-house as possible, and removed from all they are not supplied by separate steam-lines, stop-valves must that all outlets of steam may be instantly closed if a steam-pipe y in connection with it bursts during a fire.

ity of water required at a fire at a moment's notice makes it to keep a large storage always on the property, unless there are obt ining an unlimited supply from outside sources, as in the case of ies on the sea-shore or near a lake. It is inadvisable to keep open ambars of water on the property, as it is almost impossible to prevent a film of oil from collecting upon exposed surfaces, which are themselves a source of danger; nor should water, if it can be avoided, be left on the property to filter back into the ground to undergo rebailing. Surplus reservoirs, which are only sometimes needed for oil, may be used. here possible, underground masonry nks for measuring oil may be em , the larger portion being kept filled th water, and the upper used for s of oil; but if these are needed to deal with an increased pro ction or re diminished facilities for disposing of the oil, the water m e pump at, and stored in earthen open ambars temporarily. The hyd th main should not be less than 2½ inches, and should be fi d ed unions and connections which are interchangeable. of good quality flaxen canvas, for leather and many materials will not stand quality of the water and frequent contact with oil. Much trouble xperienced in finding a reliable and long-lived quality of hose, and i ent. of the fires it will be observed that two-thirds of the hoses burst, and are quite useless the moment water is passed into them. Some experienced hands insist that rotting is retarded and the life of a hose prolonged by pumping crude oil through it before it is used for water, and make a practice of always treating a new hose in this way. The common size of hose is 2½ inches. After use it should be carefully washed by pumping through it sea or fresh water, and then slung up to dry in a place which is well ventilated, and only coiled up when perfectly dry. The branches should be made of copper, and as light as possible consistent with the pressure, and should be fitted with detachable nozzles, and unions made to gauge. The nozzles generally in use on the oil fields range between ½ inch and ⅝ inch, which size is absurdly inadequate for dealing with such fires as take place on oil properties. Nozzles should not be less than ¾ inch or ⅞ inch, and when fed with a plentiful supply of water at a pressure of not less than 120 lbs., a destructive stream of water can be made to reach the summit of the highest derricks.

Particulars of jets from fire nozzles with a pressure of 100 lbs. at the nozzle.*

¾-inch nozzle.	136 gallons per minute.	Vertical height of jet 83 feet.
⅞ " "	186 " "	" " " 90 "
1 " "	245 " "	" " " 96 "

Fire-hoses should be in lengths of about 150 feet, and should be stored at convenient places on the property in small boxes that are provided with a wooden drum, upon which the hoses can be rolled when not in use. What is

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* From Kemp's "Engineer's Year-Book."

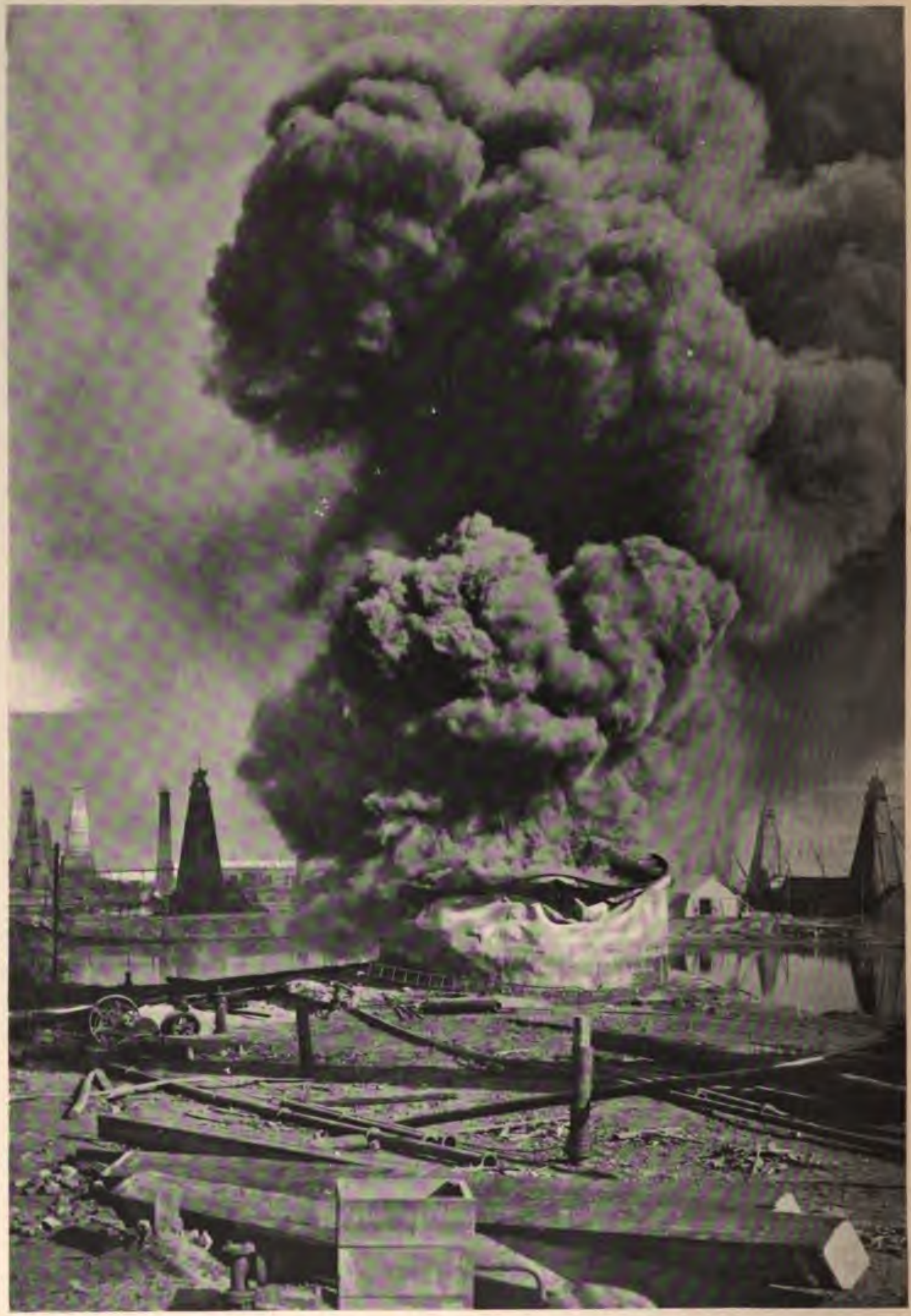

Fig. 87.—A Reservoir of Oil on Fire at Bibi-Eibat.
(Showing damaged state of iron reservoir.)

most needed at the commencement of a fire are a few clear-headed, calm persons to instruct the workmen what to do, and where to concentrate their energies, for unless so led, the men run excitedly hither and thither, each one ordering another, and no one doing any profitable work towards confining the extent of the fire. The stores should be opened, and sheets of felt, shovels, hatchets, buckets, distributed to a number of men, with definite instructions where to proceed. All woodwork, chutes, and inflammable materials in dangerous proximity on the windward side should be smashed down and removed, and the derricks stripped of their timber covering. On the leeward side everything that can transmit fire, such as fences, chutes, etc., should be destroyed, and everything should be done by means of water to prevent the ignition of the derricks. The spread is so rapid in this direction that there is generally no time for stripping and cutting down the derricks, and if all hope of saving them is given up, workmen should be ordered to cover the engines and machinery with sand, in order that they may be protected from the heat. When once a derrick is alight no more water should be thrown upon it, otherwise the engine, which will in ordinary cases survive a fire with little damage, will be split in many places, and rendered almost useless. The roofs of reservoirs, tanks, and vessels containing oil should be covered with damp sheets of felt, and even covered ambars which have become ignited may be suffocated by a judicious arrangement of planks, sheets of felt, and sand over the man-holes. Burning reservoirs of oil erected above ground are not dangerous so long as the iron does not collapse, but unfortunately this often happens, and rivers of burning oil run in all directions, spreading destruction everywhere in their path. In one case in the Saboontchy district a large fire had practically subsided, when a burning reservoir full of oil burst, and the stream of burning oil flowed down the main road towards the Saboontchy Station, entered the canal, into which it was diverted by a sand-bank, and set fire to numerous other derricks situated near the canal. In the autumn of 1902, a similar disaster caused terrible destruction of property in the Bibi-Eibat field, and led to a small fire assuming immense proportions.

No restrictions are enforced with regard to reservoirs for oil, which are usually erected on *raised ground*, and it is simply terrible to imagine what appalling results would have taken place if some of the burning reservoirs had burst during fires in the Balakhany-Saboontchy field. Reservoirs of oil should always be placed in a hollow, or be surrounded by an embankment or wall, which encloses a piece of ground capable of containing the total capacity of the tanks or reservoirs, or be fitted with very large exit valves leading to an open ambar, in which the oil may be kept in safety or allowed to burn harmlessly away.

Considering the inflammable nature of everything upon an oil field, it is almost miraculous how so much property escapes destruction during a big conflagration. The author has been actively engaged in many large fires, and it would really seem that Providence had arranged for some plots to come untouched out of the most exciting ordeals. In one example, not only sparks, but large flaring pieces of timber were falling in showers upon an actively exploited oil property, being carried thither by a strong wind nearly half a mile, and although the blazing pieces were deposited in numbers upon open ambars of oil and oil-soaked derricks for more than half an hour, nothing took fire. Certainly the fire service was not responsible, although it no doubt assisted to avert the danger, but in the cool night the oil appears to congeal somewhat, and unless well heated up by an adjacent fire does not readily ignite. Oil stored in open ambars, unless quite fresh from the well, has been converted into mazoot from loss of the lighter products during exposure, and unless a burning fragment of wood remains in contact with this for some time without being extinguished, it will not burn. Every year the fire problem is becoming a more serious one, and demands stricter attention, for the derricks are gradually becoming more and more congested in actively exploited districts, and have already in numbers of places become so thick that a big conflagration cannot possibly be avoided if a fire originates in their midst; indeed, some properties are so badly situated and so carelessly mapped out that there is a serious danger of all escape for the employees being cut off in the event of a sudden outbreak.

Fires frequently destroy from forty to fifty derricks, besides numerous reservoirs, dwellings, etc., and occasionally as many as two hundred are burnt in a single night, besides thousands of poods of oil and many thousand pounds' worth of machinery. Many acres of oil-producing ground are, in the course of only a few hours, devastated, and then become for the next few weeks the scene of the liveliest activity whilst the re-erection is in progress. In September, 1902, one large fire in the Saboontchy district had scarcely been suppressed, except for a fountain that still vigorously burned, when a second and quite distinct one originated, of even larger proportions, in Romany, which in turn led to a third outbreak in yet another part of the field. The two separate fires in different parts of the oil field produced a most weird appearance, which was not lessened by the magnificent fountain of Musa Nagieff, which burnt fiercely almost until daybreak appeared.

Fountains on Fire.—Fountains often take fire, and sometimes continue to burn for days and weeks, during which time not only thousands but tens of thousands of pounds' worth of petroleum disappears in smoke. Flowing wells are a serious menace to the district in which they are playing, on account of the enormous volumes of highly combustible gas which accumulate and penetrate into all the buildings in the vicinity. On a still day the danger is greater than on a windy day, as the gas, which is three times as heavy as air, collects near the ground, and is not diffused into the atmosphere and dispelled by the wind.

In 1897, a fearful disaster took place on the Russian Petroleum and Liquid Fuel Co.'s plot at Bibi-Eibat, through the gases on a very calm day penetrating the boiler-house, after traversing a considerable distance unobserved. The explosion that followed killed and injured a large number of workmen, and led to a fire which, besides destroying the greater part of the property, inflicted a loss of many thousands of pounds through the burning of the fountain oil. When a fountain commences to spout, all boiler-houses should be shut down, and all fires in dwelling-houses, blacksmiths' shops, etc., extinguished for a long distance on the leeward side, wherever the strong, pungent odour of petroleum gas is noticeable; indeed, the police now issue instructions to put out all fires

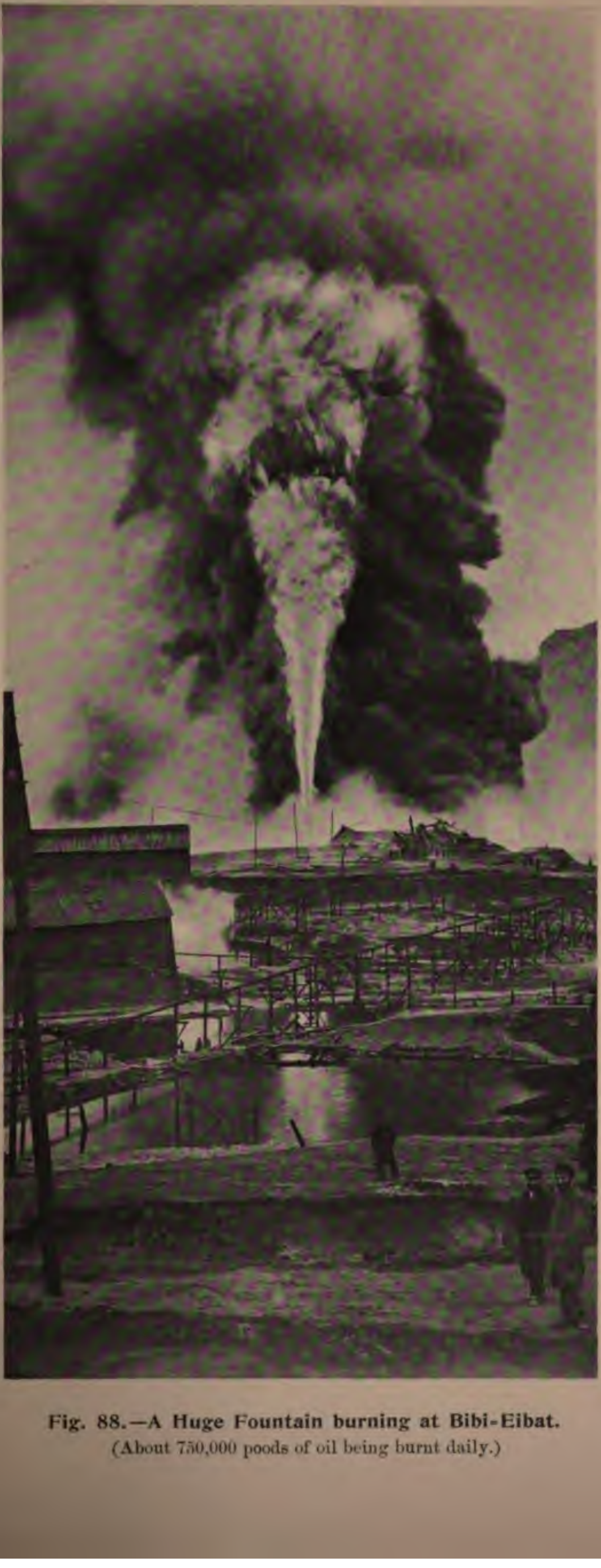

Fig. 88.—A Huge Fountain burning at Bibi-Eibat.
(About 750,000 poods of oil being burnt daily.)

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within a certain radius, and carry out their orders with force, if necessary. A fountain, when once on fire, is no longer a source of danger to surrounding property, for it emits no sparks, and the whole of the oil expelled is consumed in the vertical jet, which rises to a height of a hundred or more feet, and burns with great heat and luminosity, accompanied by huge volumes of jet black smoke. Fountains which have been burning nearly half a million poods a day, representing a loss of about £100 per hour to the unfortunate owner, have not been uncommon in the Bibi-Eibat oil field, and for a whole week Baku has been illuminated with sufficient brilliancy to permit reading in the streets all night as the result of the glare from burning fountains at Bibi-Eibat, several miles away. In one fire at Romany, in 1898, three fountains were burning simultaneously; and recently in 1901, a fountain of the Schibaieff Co. at Bibi-Eibat burned a whole week before its force was expended and it could be extinguished. In a recent disastrous fire in the Bibi-Eibat oil field (autumn, 1903), sixty-five derricks were burnt, besides numerous reservoirs, buildings, and over 10,000,000 poods of oil; and at one time as many as five fountains were burning simultaneously. One fountain burned without cessation for about three weeks.

Numerous devices have been suggested for extinguishing burning fountains, which can usually, unless very large, be closely approached on the windward side by men properly dressed for the purpose, but it is doubtful whether any apparatus yet invented is of real practical value. The principle of such appliances is, as a rule, based upon slipping a tube fitted with an open valve over the well-casing, through which the fountain may play unresisted, until the fitting is firmly anchored to the ground or to the tubing, after which the valve may be suddenly closed by a rapid motion, and the flow stopped. Although some such device did actually extinguish the Schibaieff burning fountain, it was only when it had almost played itself out, and the pressure was nearly exhausted; but it is extremely doubtful whether any contrivance could be employed which had not previously been attached, in the presence of such a terrific heat, and a pressure of from five to twenty atmospheres on a tube 10 to 16 inches in diameter.

In America, spouters have been extinguished by an unlimited application of chemicals which will not support combustion, and in a recent case in Texas, steam, directed on to the flames in sufficient quantities, is reported to have met with success, but the dimensions of the tubes, and the pressures exerted, did not compare with the Russian wells. The cost of an efficient fire service is large, and it comes very hard on many small firms to install a service of practical value. The authorities, who have stepped in and insisted on so many improvements in the industry, and so many regulations to ensure the safety of the district and comfort of the workmen, seem to have overlooked one of the most important necessities of the district, viz., a well-equipped and well-trained fire brigade and salvage corps, supplied with the most modern appliances obtainable, and led by an experienced and calm commander. The first urgent necessity is, however, a large fire service main encircling the whole district, with frequent connections and branches to all exploited properties, to which hoses may be attached, or suctions led to powerful pumps, which will still further increase the pressure. The brigade should be provided with several high-pressure steam fire-engines to act in conjunction with the fire main, and the salvage corps of trained men, led by competent superiors, should be given every instrument needed for their work of preventing the spreading of fires. All fire fittings used in the oil fields should be of standard size, and every company should be made to replace those in use by those of a standard size named by the local authorities within a stipulated period, in order that the fire brigade's own fittings may be used if necessity demands.

CHAPTER XV.

ADMINISTRATION OF OIL PROPERTIES.

Administration of Oil Property.—Types and peculiarities of employees—Qualifications of managing engineer—Managing engineer's personal staff—List and description of departments: Mechanics' shop, boring department, tube works, bailer shop, electrical department, carpenters' shop, stables, measurement and delivery of oil, inspection and splicing of wire ropes, boiler shop—Severe character of Russian labour laws—Cost of raising oil on the Russian oil fields—Need for writing off substantial sums annually—Strictly technical nature of the oil business—Disagreeable conditions under which Europeans on the oil fields work.

CHAPTER XV.

ADMINISTRATION OF OIL PROPERTIES.

Administration of an Oil Property.—The unexampled mixture of Eastern and Western races found on the Russian oil fields—an idea of which may be found by a glance at the Baku labour statistics in Chapter IV.—is full of interest to a student of character, and the widely divergent idiosyncrasies of the different races are strangely contrasted to one whose daily duty brings him into contact with these varying types of men, to whom even a modified mode of address must be used by a tactful and considerate manager. One cannot but admire the good-natured, thriftless, hard-working, and hard-drinking Russian labourer, who, although completely overcome by the vodka which he has too freely imbibed, contents himself with nothing more harmful than singing lustily, and who allows himself to be led home by a wiser companion or a dutiful wife, almost childlike, without the least resistance. The entire reverse is to be found in the Armenian workman, who rarely drinks, is thrifty in the extreme, and banks every copeck left after purchasing the barest necessities of life; whose keen eye shows the business qualities inseparable from his race, and whose sharp retort proves the working of a fertile brain. The Tartar and Persian employees of the peasant class arouse a feeling almost akin to pathos by their absolute simplicity, their imperturbable countenance, that no amount of bullying will disturb, and their implicit faith in Allah, before whom, at sunset every evening, they prostrate themselves and offer up their prayers, wherever they may be, and however important may be their occupation. At sunset the Tartar attendant may often be found kneeling behind the bailing drum in the derrick, upon a short piece of wood which he conceals for the purpose, muttering his devotions, and more than one guilty Mahommedan has escaped a well-deserved punishment from an irate manager by prostrating himself and diligently praying on the principal's approach; the hardest master can scarcely gather up sufficient courage to arouse a man from his prayers in order to give vent to his suppressed anger.

The totally different religions and characters of the various races engaged in oil exploitation make it necessary to have separate barracks for their shelter, and unless this provision were made, serious disturbance would assuredly originate, that would often lead to bloodshed. Not only does religion necessitate this separation—although the periods of feasting and fasting which precede and follow certain festivals, the dates of which do not coincide, must in themselves create ill feeling—but the modes of living and eating are quite dissimilar, and whilst a Russian cannot exist without his vodka, the Tartar and Armenian rarely consume intoxicating beverages. The Mohammedans also survive on the simplest and meanest of diets, their food being almost exclusively confined to bread and, in the proper season, raw cucumbers, water-melons, grapes, etc., when sufficient may be purchased for a copeck or two to last a day. The Russians and, to a less degree, the Armenian workers require a more substantial diet, and partake of soup, meat, and other luxuries in addition to the bread which forms their staple food.

The Caucasian-Tartar and Persian workmen are quite unfit for work of a laborious nature, and although they can endure a wonderful amount of exposure, they are physically useless for heavy duties, and quickly succumb under excessive tasks. The Russian labourers have much more stamina and determination, and will exercise two or three times as much strength as Tartars; but no prolonged work can be undertaken without liberal intervals for resting, smoking, and drinking vodka, and the smallest weight cannot be raised without a song, in which the whole of the labourers engaged take part. The chief man is generally a person whom Providence has provided with vocal gifts, and he leads off the songs in which the remainder join.

The fierce Lesghians and Groozines exhibit undeniable traces of their mountain origin even to this day, and one can imagine the spirit that led them for so many years to resist the Russian invasion of their rocky retreats. They belong to brave, fearless tribes with more than usual intelligence, and were it not for their quick temper they would form—and they do even now, to a large extent—one of the most valuable races for oil-field work.

The law stipulates that a qualified engineer with Russian diplomas must be placed in charge of an oil property, and held responsible for its conduct in accordance with legal regulations relating to the industry, but foreign companies usually appoint an engineer to represent their interests, who acts in conjunction with the official manager, a situation that sometimes leads to difficulties, but one that can scarcely be avoided on account of the mass of official work connected with a large company. The managing engineer's qualifications should not be confined to a particular branch, for his duties are of a most varied nature, and he should, besides possessing some administrative abilities, have a sound knowledge of mechanical engineering, some acquaintance with building construction and surveying, and be familiar with boring work, geology, and chemistry.

The managing engineer's office should be situated as centrally as possible on the district where the exploited properties are located, so that he can interview and consult with members of his staff without causing long departure from their duties, and may himself be within easy reach of his books and journals relating to the work. An assistant manager is generally entrusted with the duty of carrying out the chief engineer's instructions, and the same person checks and verifies documents referring to the work before reaching the manager for perusal and signature. The head office is generally furnished with a drawing office under the directions of a qualified person, and the remainder of the office clerical staff is under the supervision of a chief clerk, who is responsible for the verity of the books and documents. The clerical staff is divided into several departments. The compilation and preparation of official information demanded by the authorities is under the charge of one person; the disbursement of incidental expenses, collection of fines, rents, etc., is under the directions of a second; the registration of workmen, collection and tabulation of passports, and preparation of wages sheets, are the duties of a third department; the book-keeping of materials and verifications of accounts, etc., are the tasks of a fourth branch; but on a small oil concern one or two clerks may perform the whole of the work.

On each property, or group of plots in proximity to one another, is stationed a property clerk, whose work is to keep the employees' time, instruct the men in their duties, regulate the bailing according to instructions, receive and order materials from the main store, and generally supervise the work on the plot, and report by telephone any irregularities needing a decision from the chief; but on very large properties an engineer is retained for the purpose of managing a defined area.

A mechanic or machinist is also attached to each property, who is, according to the size of the plot, provided with one or more assistants and greasers, and he is held responsible for the proper maintenance of all engines, boilers, and machinery in work.

On a large oil property there are the following thirteen departments, in addition to the supervision of the various plots:—

(1) Managing engineer's personal staff.
(2) Engineering staff.
(3) Clerical office.
(4) Mechanics' shop.
(5) Boring department.
(6) Tube works.
(7) Bailer shop.
(8) Electrical department.
(9) Carpenters' shop.
(10) Stables.
(11) Measurement and delivery of oil.
(12) Inspection and splicing of wire ropes.
(13) Boiler shop.

(4) The mechanics' shop is an indispensable adjunct to every oil property of moderate size, for repairs and renewals are constantly needed to the engines, bailing drums, boring machines and instruments, pumps, pipe-lines, and other fittings that are exposed to specially unfavourable conditions on an oil property. The workshops are placed under the directions of a foreman, who is assisted and instructed by the engineering assistants, but who is held responsible for the proper completion of work entrusted to him. He should be thoroughly conversant with ordinary repair work, and should not be without some acquaintance with boring tools and appliances. The wages of artisans, etc., engaged in the mechanics' shops are as follows:—

Head foreman mechanic	150	to	200	roubles	per month
Timekeeper	50	,,	70	,,	,,
Fitters	2	,,	3	,,	per day
Turners and machinists	2	,,	3	,,	,,
Blacksmiths	2	,,	4	,,	,,
Strikers	1	,,	1·20	,,	,,

An oil property workshop should be provided with several lathes of from 8-inch to 12-inch centres, a planer, a shaper, a slotter, several drilling machines, pipe and bolt screwing machine, ½-ton power hammer and a fan.

(5) The boring department is generally conducted by a head boring-master, who supervises the whole of the boring and repair work, and reports to and consults with the managing engineer each day. In each boring or repairing well there are two shifts of men each under the charge of an assistant boring-master. The gang is made up as follows:—

2 assistant boring-masters (one day, one night)	40 to 60 roubles per month
2 brake-men (for operating the boring machine)	22 „ 25 „ „
2 wrench-men (for screwing up the rods)	20 „ 23 „ „
4 common labourers	18 „ 20 „ „

Usually the work proceeds night and day without cessation, except for meals, but when specially dangerous and laborious work is in progress, such as difficult fishing, or lowering tubes, it is usual to work only by day and employ the whole gang.

(6) The tube works are fully described in Chapter VI., which is devoted solely to the subject of well-casing. When tubes are manufactured on the day-work principle, the following are the approximate wages:—

Timekeeper or overseer	50 to 70 roubles per month
Head tube-maker	60 „ 100 „ „
Riveters	25 „ 35 „ „
Labourers	18 „ 20 „ „

A single tube, when made by contract, costs about 1·50 roubles without materials or tools.

(7) The bailer shop must be a well-organized department, placed in the hands of a man who must keep all the wells provided with bailers, and see that no stoppages arise from scarcity. The shop must be furnished with one or two forges for heating the soldering irons, a set of rolls for bending the iron sheets, and a number of rails, supported at one end, upon which the riveting is done. The wages of the artisans, etc., engaged in this department are—

Timekeeper or overseer	50 to 70 roubles per month
Head bailer-maker	80 „ 100 „ „
Common bailer-makers	2 „ 3 „ day

The bailer works should be centrally disposed amidst the chief producing plots, where a single establishment is run; but some companies prefer to erect a branch bailer-repair shop on very large properties, and thus reduce the amount of carting.

(8) An electric light installation is essential to every oil property, for day and night the oil-property work proceeds, unless interrupted by a fire or an accident. Electric light may be purchased from electric lighting companies on the oil fields at a fixed charge per lamp; but most enterprises find it infinitely cheaper and much more convenient to erect their own installations for the generation of light, and retain a small staff for the maintenance and operation of the plant and fixtures.

Very cheap electric light stations may be installed by erecting small high-speed steam-engines, such as may be purchased from Messrs. Robey and Co., of Lincoln, and Messrs. Ruston and Proctor, of Lincoln, and one or two German firms, but a better plant may be arranged by fixing a slower-speed Marshall or other vertical type of high-class engine. Most Baku companies owning a number of separate plots, adopt the principle of a central station, and conduct the current about the oil fields by means of wires on poles; but some concerns prefer to have a small engine and dynamo on each plot, of just sufficient strength to light the single property. If the central-station plan is adopted, and all the oil lands rely upon illumination from this source, a reserve dynamo must be kept for cases of emergency.

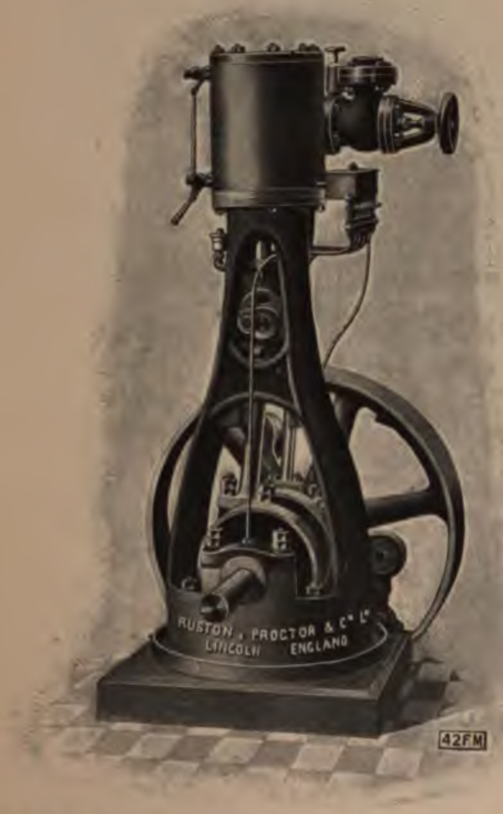

Fig. 89.—Ruston and Proctor's High-speed Vertical Engine for Electric Driving.

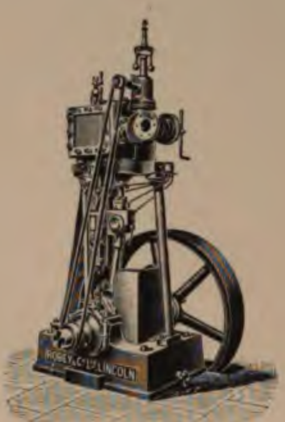

Fig. 90.—Robey's High-speed Vertical Engine for Electric Driving.

These engines are extensively used on the Russian oil fields.

The staff and wages connected with an electric light plant are—

Head electric mechanic	70 to 100 roubles per month
Assistant electric mechanics	40 „ 50 „ „
Greasers for engines and dynamos	23 „ 25 „ „

Where electrical energy is employed on the oil properties, a large staff of electrical mechanics is needed to keep the motors and installations in good working order.

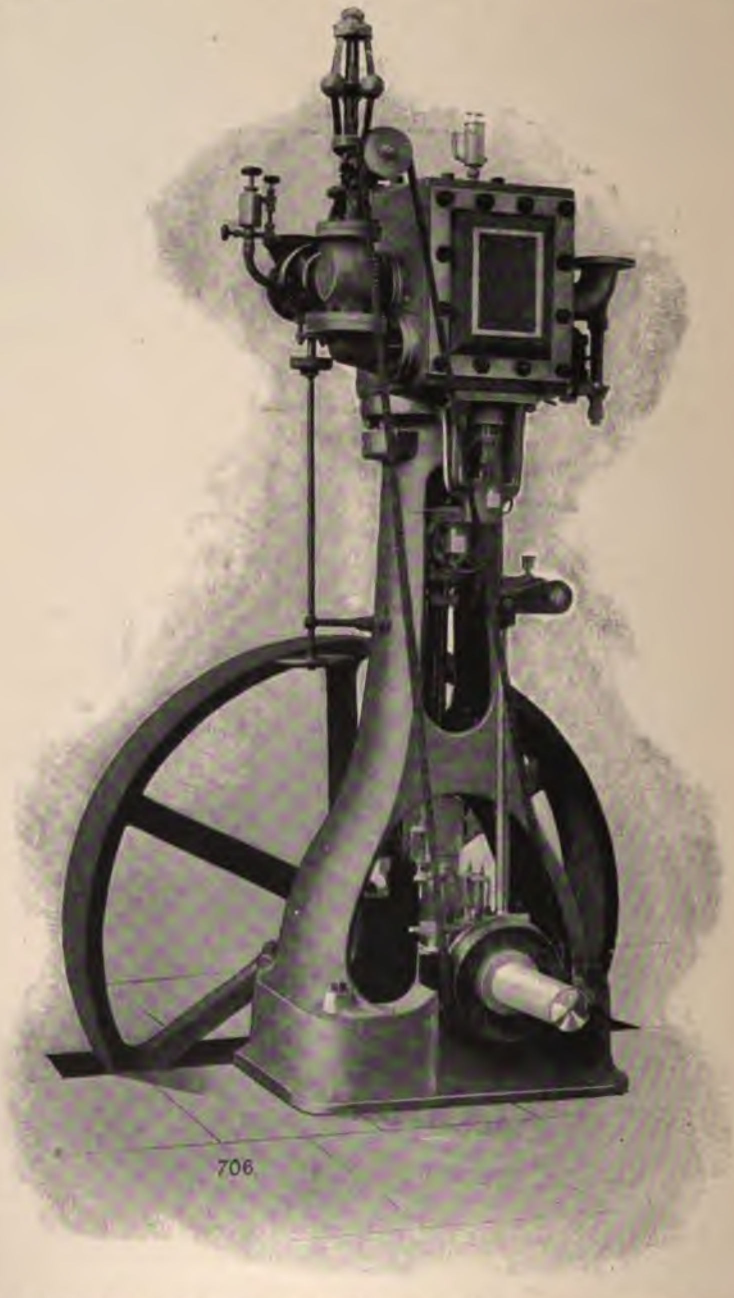

Fig. 91.—Marshall's High-class Vertical Engine, largely used in Baku Oil Fields for driving Dynamos.

(9) A carpenters' shop is inseparable from an oil property, and it is really

amazing what an amount of timber is disposed of on an average oil plot, even if the greatest economy is exercised. There are endless, hourly repairs and alterations to derricks, foundations of engines, wooden structure of machinery, chutes, etc., besides the manufacture of settling tanks, bailing tubs, and other accessories, and the replacement of bailing pulleys, friction blocks on drums, and such-like work. The wear and tear on an oil property is excessive; accidents are frequent, and machinery is always being moved from place to place for repairs and renewals, all of which, in Russia, necessitates the assistance of carpenters. Carpenters are paid as follows:—

Foreman carpenter	60 to 80 roubles	per month
Carpenters	1·5 to 2 „	day

(10) The work of a large oil company cannot be carried on without efficient transport conveniences, and the cost of this item is often no inconsiderable amount when all the expenditure on renewals and repairs to carts and phaetons is taken into account. Saddle-horses and conveyances are necessary for the rapid movement of engineers, assistants, boring-masters, and other overseers, whose duty is to control the different departments.

Two-wheeled and four-wheeled carts are imperative for the conveyance of tubes and instruments, the removal of materials and goods to the plots, the changing of bailers, etc.; in fact, there is found to be a constant need for transport vehicles on a large oil company. The wages of men connected with such an establishment are—

Coachmen for phaetons	25 to 30 roubles	per month
Carters	22 „ 25 „	„
Grooms	18 „ 20 „	„

Good horses cost from 250 to 400 roubles, and common horses or ponies from 100 to 200 roubles.

(11) The measurement and delivery of oil is usually made by a trusted person, assisted by others if necessary. Each morning a correct measurement is taken of the previous day's yield, after running away separated water, and allowing some 10 to 15 per cent. for water still in suspension; the necessary valves are then sealed, and instructions given for the delivery of the oil to a common storage or other place indicated. The delivery-man takes measurements of each property in succession, and then arranges for acceptance of the oil by the persons to whom it has been sold, or, in the event of the company owning its own refineries and pipe-lines, he acts on instructions from head-quarters.

On ground leased from the Government the delivery-man must be present with the Government official, and an agreement must be arrived at as to the correct quantities in the reservoirs.

(12) The inspection and splicing of wire ropes call for the service of men with a special knowledge of the art of splicing. Several men are engaged exclusively for this work on a large oil concern, and their duty consists in keeping a record of the wire ropes in use, carefully inspecting them periodically, and renewing, repairing, or splicing on a new piece whenever such a course is rendered advisable. Skilful rope-splicers are valuable men on an oil

property, as, apart from the bailing ropes, there are numerous other ropes used in boring, etc., that need occasional attention. The rope-splicers should always supervise the winding of a new rope on to the bailing drum, as a novice may seriously injure a new rope by allowing knots or kinks to form. A first-class rope-splicer's pay is 50 to 70 roubles per month.

(13) Few oil syndicates have a boiler shop, but nearly all retain in their employment one or two boiler-makers to carry out small repairs to the boilers as occasion demands. Small patches are often needed; seams have to be caulked; faulty rivets must be removed and replaced by new ones; new furnace tubes have occasionally to be inserted, so that on a property of moderate proportions there is constant employment for a boiler-maker and an assistant or two. The rate of pay is usually—

Boiler-maker	50 to 70 roubles per month
Assistant boiler-maker	30 „ 50 „ „

The administration of a Russian oil property cannot be conducted without a thorough acquaintance with the Russian laws dealing with labour, the safe working of mines, and special laws compiled for the benefit of the petroleum industry, the most important of which will be found in Appendix B. The regulations relating to labour are particularly strict, and it is doubtful whether a workman is better protected by legislation in any country in Europe. The severity of the labour laws often leads to imprisonment of the responsible engineer when workmen are killed or injured, whilst insurance against employers' liability is even more necessary than in England.

The cost of labour on the Russian oil fields is very small compared with most European countries. Taxation of a direct form is not excessive, although there has been a tendency during recent years to increase the taxation on profitable enterprises. But the expenses incurred in the management of oil companies are rather great, especially where thoroughly qualified persons are engaged to superintend and conduct the affairs of the companies.

The cost of raising oil from wells on the Baku and Grosny oil fields, including all expenses of management and administration, taxation, etc., but exclusive of royalties or rents, varies from about 2·5 to 3·5 copecks per pood, and a fair average would probably be 3 copecks per pood. It has been shown, in previous chapters, that the life of wells is short, not on account of exhaustion of oil, but through the prevalence of accidents to the casings, which result in exclusion of oil or the inlet of water. Experience has proved that from 2·5 to 3 copecks per pood must be allowed for the boring of new wells and the repairing of old ones if the production is to be maintained. Fountains may reduce the sum necessary to be set aside for boring work, and specially prolific properties may require a much less expenditure to maintain a regular output. Fountains, however, should not be anticipated, but should be considered rather as fortunate incidences if they occur. Three copecks per pood will generally be found to be a good average sum to deduct from revenue for exploitation purposes.

Royalties in kind vary from 15 to 50 per cent. of the production, but the common royalty is 25 per cent.; consequently, where the oil-bearing land is not freehold, from 2 to 3 copecks per pood have to be added to the expenses, which addition raises the cost of oil produced to 8 or 9 copecks per pood. Where lands have been purchased outright, a similar amount of from 2 to 3 copecks per pood will usually suffice to pay off the whole of the purchase price in 10 or 12 years, which time is as long as a sound business policy demands on an average oil field. A Baku oil property may yield a remunerative production of petroleum for 15 or even 20 years; but it is obvious that the life of the land is largely dependent upon the extent of exploitation and the presence and activity of neighbours; consequently, a provident company should, except in special cases, allow for the total amortization of its properties in 10 or, at the very extreme, 15 years. It will thus be seen that companies which confine themselves to producing oil, holding oil lands under average Baku conditions, cannot possibly flourish unless the price of crude oil is 12 copecks per pood; and certainly many Baku producing concerns can only pay a reasonable dividend, even if very little is allowed for amortization, when the price of oil remains at 15 to 16 copecks per pood. Numerous companies exploiting oil in the Baku fields were induced at periods of prosperity to pay from £5000 to £10,000 per dessiatine in addition to a 25 per cent. royalty—a state that obviously allows of remunerative results only at prosperous times. To summarize—

Average cost of raising oil	3	copecks per pood
Average cost of new wells and repairs . . .	3	,, ,,
Royalty (at 25 per cent.) or Amortization (at 12 years) (approximately) . .	3	,, ,,
Profit	3	,, ,,
	12	,, ,,

Where, in addition to a royalty having to be paid, an amortization has to be allowed for on a large initial payment, nothing less than 15 copecks can permit of a profit, if reasonable provision for amortization has to be set aside.

A reader of this volume who was previously unacquainted with the subject may have been under the impression that "boring for oil" was a very simple affair, and all that one had to do was to bore a hole into the stores of petroleum hidden beneath the soil, and Nature would do the rest. But a perusal of this work cannot fail to have convinced him how exclusively technical are many of the operations required for the successful carrying on of an oil property; and the unprejudiced reader will also have perceived that upon the exertions of the engineer—it is not too much to say—depends the success of an oil-producing company. An engineer, however capable, cannot make oil; but he can see that due provision is made for securing the maximum quantity of oil obtainable from the land he exploits; that the best work to that end is conducted under his supervision; and that the plant and machinery under his care are maintained in thorough efficiency. Not only is the engineer responsible for many thousand pounds' worth of plant and machinery, and for the discipline of perhaps hundreds of uneducated workmen, belonging to a dozen or more races, and speaking half as many different languages, the settlement of whose petty grievances forms no small part of his daily duty; but he alone is held responsible by the Government for accidents to his workmen and the proper conduct of the work, in accordance with the special regulations relating to the industry, whilst upon him devolves the ultimate responsibility for the profitable outcome of the operations of an oil company; yet to the shareholders, and often to the directors, he is often an almost unknown entity. Little wonder, then, if thus "out of sight," he is often inclined to consider himself "out of mind," and to gravely doubt whether his services are appreciated or adequately acknowledged by the company he serves.

Notwithstanding the strictly technical character of the work, few oil-producing companies have yet realized the importance of dividing the management of an oil property into its two natural departments—the engineering and the commercial—unless the engineer himself can conduct the commercial department.

Where companies neither refine nor distribute oil, but simply sell the output of their wells, a separate commercial department is not required, for the whole of the work, both of administration and of disposal of output, can be performed by the staff at the wells, and a town office in Baku would mean little more than a repetition or copying of books or records kept at the works. Where producing companies speculate in oil, a separate department in Baku will probably be found necessary; but if the history of English companies be traced, it will generally be found that losses have followed such speculations, and this is likely to be always the case. Producing companies will make a much better average profit if content to sell their product on the market to firms of sound position engaged in refining and distributing, who are always willing to buy, if not at the official price, yet at a figure only differing by a mere fraction.

Messrs. Nobel have long appreciated the advisability of separating the technical and the commercial departments, and their great success on the oil fields shows the wisdom of this division. In too many cases commercial managers have been allowed to interfere with the details of the engineering departments, and to this interference may be traced much of the non-success of many oil-producing companies. The engineering department of an oil property should be under the exclusive control of a responsible engineer, who should be in direct correspondence with the managing director or board of directors of the company, and it should be a fixed rule of practice that all reports and representations made by him should pass direct into their hands for consideration. By this means responsibility for his department is put (as it should be) on the engineer only, and if he so far enjoys the confidence of the board as to feel assured that communications from him will be welcomed and duly considered, any question as to his capability or incapability, should it arise, will make itself apparent to the board of directors, and they can act without hesitation as circumstances may require.

For the English and other European officials on the oil fields the questions of residence and leave of absence are important. Baku cannot be said to be a very desirable place to live in, but the oil fields, with their wells in constant operation, are worse. There, holidays are almost unknown, and even the weekly break of Sunday is often non-existent. The evenings bring no complete cessation of work, but night and day, year in and year out, the work proceeds incessantly, and night after night the engineer in charge may be roused from his slumbers by alarms of fire or to deal with some serious breakdown or other emergency.

In some companies directors are liberal in their allowances of leave to officials, but the author would venture to appeal to all directors of oil companies in Russia to treat not only their engineering staff, upon whom such heavy responsibility falls, but also the clerical staff, whose duties have to be performed under such depressing conditions, with the utmost liberality in the matter of leave. The summers in the Baku region are tropical, and work there must be done under constant exposure to dust-storms and excessive heat, impairing the health of all but the most robust, unless periodical changes to a better climate can be secured.

With reference to the subject of management of oil properties, it should be mentioned that few producing companies insure their oil plots against fire. Insurance companies demand such a high premium for oil properties that most concerns prefer to set aside a definite sum annually to meet exigencies of this nature. Insurance companies will only insure the goods for 60 per cent. of the value (at their own valuation), and will only agree to these terms when everything belonging to the company is included in the policy.

Before dismissing the subject of management, a few interesting facts might be conveniently introduced concerning the great Russian Empire—an empire having an area of about 8,660,000 square miles, or nearly one-sixth of the land area of the earth. Russia's population exceeds 135,000,000, and the mineral wealth hidden in the Caucasus, the Urals, and in Siberia is probably exceeded in value by no other country in the world, yet she lacks the capital necessary to recover the wondrous treasures. No more marvellous example of the mineral wealth of Russia is needed than the Baku oil fields, where less than six square miles of barren desert yield nearly half the world's supply of petroleum. 2000 wells grouped together within an area no larger than a London suburb yield as much petroleum as 20,000 wells spread over several thousand square miles of land in the United States. One Baku well has yielded in a month as much as the total annual production of Galicia. One single Bibi-Eibat plot of 10 dessiatines (27 acres) has for ten years produced as much oil annually as the total yearly yield of Galicia, and about twice as much as Roumania.

On reaching the Russian frontier station, all passports are demanded, and unless these are forthcoming on request, the travellers will be escorted back by the next train. Whilst the luggage is being examined, the passports are inspected by a staff of officials, and when these are checked, the names are called out in the waiting-room. When the Russian frontier is passed, the traveller is at once plunged thirteen days back, and he will discover, on referring to the local calendar, that he has performed the journey from London to the frontier in minus eleven days. The confusion arising from this difference of dates is overcome by attaching to letters for foreign destinations both dates; thus, Jan. 1st old style would be written Jan. 1/14/04.

Railway travelling in Russia is the cheapest and most comfortable in the world, but, unfortunately, it is almost the slowest; and although the journey to Baku is one of the easiest runs in Europe, the business man yearns for the Western expresses. The railway carriages are designed for comfort. The *coupés* are lofty—as tunnels are rare in Russia,—and only four passengers are allowed in one compartment, for which " platz-karten " are issued. The seats are opened up at nights to form beds, and sheets and blankets are provided at a nominal charge (one rouble for the journey). Few trains are provided with restaurant cars; but, to compensate for their absence, there is a well-organized system of providing first-class buffets at stations. Passengers are notified of the duration of stoppages at the stations by bells: one bell indicates that the train will leave in fifteen minutes; two bells indicate that five minutes remain; and three bells signalize the departure of the train. The food at the station buffets is generally both good and remarkably cheap. A *table-d'hôte* meal with four courses may often be obtained for a rouble, whilst a chicken, duck, and other poultry cost but fifty copecks (one shilling). Excellent soups, for which Russia is noted, are always obtainable at a small figure; mineral waters are cheap (and no other water should be touched); Caucasian wines cost from fivepence per bottle; and excellent Chinese tea is everywhere procurable at threepence per glass. The samovar is the national institution, and is everywhere in evidence, for the Russian cannot exist without his tea. In almost every office in Russia the samovar is kept busy most of the day, and the employees are provided gratis with as much tea as they can consume. At the elbow of each clerk will be found a glass of tea, which he constantly sips; and no visitor can enter an office without the hospitable invitation to a glass of this refreshing national beverage.

Russia provides its citizens with more holidays than any other country in the world. There are, in addition to Sundays, about forty national holidays in the year, equivalent to bank holidays in England, when all shops and business houses are closed by law, except a few industries prescribed by decree, where the stoppage of work would entail serious loss. The oil industry comes under this exemption; but double pay must be given to employees who work on these holidays. The enforced cessation of all work and closing of Government offices, shops, and workshops imposes a heavy burden upon commercial enterprise.

It is only natural that in a country which embraces a large portion of two continents, and encircles about one-fourth of the globe, there should be difficulties over the time. In Baku, Tiflis time was, until a few years ago, the official time; but now St. Petersburg has been given this distinction, and there are in use in Baku three distinct times, viz., local, Tiflis, and St. Petersburg. Such a condition causes much confusion, for, unless the time is indicated by some mark of explanation, one gets hopelessly mixed. Railway times are now all St. Petersburg; and station clocks are often provided with two pairs of hands, red ones indicating local time, and black ones St. Petersburg time.

The passport regulations in Russia are most severe. No one dare shelter a person unprovided with a passport; no hotel is permitted to receive visitors unless the passport is delivered up; and there is no escape from the country unless this valuable document is forthcoming. Foreigners are allowed to use their own passports for a period of six months, provided they are *viséd* and the regulations referring to passports are obeyed; but if they desire to remain longer, foreigners are compelled to obtain a Russian passport, which, however, must be renewed annually. If the stay in the country has not exceeded six months, a foreign subject may pass the frontier with his own passport, after signature by the police in the district where he has resided; but when a Russian passport is issued, a special foreign passport has to be procured from the authorities of his district before he can leave the country.

CHAPTER XVI.

REMARKS ON THE USE AND TREATMENT OF BELTS AND WIRE ROPES.

Belting.—Large quantity in use in the oil fields—Class of belting mostly in use—Difficulties under which belts work on the oil fields.

Size and Quality of Belting.—Thickness of belting—Width of belting needed for driving bailing drums—Life of belting—" Reddaway " belting—Power transmitted by same.

Precautions to be taken to secure Good Driving.—Pulleys with rounded faces—Fly-wheels attached to engines—Fastening or jointing of belts.

Wire Ropes.—Peculiar character of work demanded from wire ropes for bailing—Ambiguity of the terms "right-hand" and "left-hand" as applied to wire ropes—Objections to flexible type of rope—Manner in which wire ropes are destroyed—Methods of reducing wear of ropes in special cases—Lengths, sizes, and makes of wire ropes.

Fishing for Lost Wire Ropes.—Kind of instruments employed for recovering lost wire ropes—Manner of using same.

CHAPTER XVI.

REMARKS ON THE USE AND TREATMENT OF BELTS AND WIRE ROPES.

Belting.—As fully 90 per cent. of the Russian wells are bailed through the medium of belting, transmitting the power from the engine to the bailing drum, the importance of proper treatment, and the purchase of a suitable quality is obvious. Although the cost of good-quality belting is very high, and its life may not exceed a month or two, unless carefully looked after, it is surprising how little attention has been given to the subject. The comparatively small circumferential velocity of the pulleys, the shortness of the drive usually allowed, the small diameter of the pulleys, and the consequently small surface of contact, greatly reduce the efficiency, and yet wells may be frequently seen working where 60 to 70 horse-power is being transmitted by a 6-inch or 7-inch belt at a velocity not exceeding 1500 feet a minute. During the last few years there has been a steady increase in the weight and width of belting used for driving the wells, which has resulted in greatly improved working and increased economy. Camel-hair belting, almost entirely of English manufacture, is universally employed, and although numerous classes of belts of other descriptions have been tried, they fail to approach in value those made of camel-hair. Leather belting is affected to a considerable extent by the oil which invariably finds its way on to its surface in oil wells, producing a slimy face that prevents a firm grip on the pulleys, and leads to constant slipping and falling off, thus prohibiting its general employment.

Size and Quality of Belting.—Camel-hair belts are often manufactured in three thicknesses, termed respectively single, duplex, and triplex. The single has been the quality in general demand, and it has had an enormous local sale, but duplex is now gaining favour, and has proved to be more suitable and longer lived. The triplex is too stout for curvature over pulleys of 4 and 5 feet diameter, which are generally fixed for bailing, and hence this belting is found to be less adapted to local conditions. If the usual formulæ were observed in calculating out the width of the belting, it would be found that belts 18 inches wide running at the common local speed would scarcely meet the demands, but as there are exceptional local circumstances, such formulæ are never employed. The unprotected situations in which the belts work, exposed as they are to changeable climatic conditions and periodical soakings with oil and water, would cause the rotting and destruction of a wide belt in about the same time as a narrow one, provided that the latter could stand the normal strain for that length of time.

A good local practice is to use 10-inch duplex belting up to a 10-inch bailer, 11-inch belting up to 12-inch bailer, and 12-inch belting up to 14-inch bailer, and if this proportion is kept, the life of a belt, when ordinary precautions are taken for its protection, is about 200 to 250 days, and may reach 300 days in wells where small bailers are used. There are many brands of English camel-hair belting, but the best yet introduced for local requirements is the "Reddaway," which may not necessarily be of the best quality or most suitable for all classes of work, but it is certainly far superior to any other brands for bailing purposes. Unlike most Lancashire camel-hair belting, it stretches very little after fixing, and seldom requires taking up; nor does it seem to be affected to the same extent as other makes by contact with oil. The intensely tough fibre composing the "Reddaway" brand causes it to resist the rough local treatment far better than all other varieties.

TABLE XXXI.

SHOWING HORSE-POWERS TRANSMITTED BY "REDDAWAY" BELTING RUNNING AT VARIOUS SPEEDS.

Velocity in feet per minute.	Width of belt in inches.												
	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	12.	14.	16.
500	1·0	2·0	3·1	4·2	5·3	6·2	7·3	8·2	9·3	10·3	12·5	14·5	16·5
600	1·2	2·5	3·7	5·0	6·2	7·4	8·7	9·9	11·3	12·4	14·9	17·4	19·7
700	1·4	2·9	4·3	5·8	7·2	8·7	10·3	11·6	13·1	14·5	17·4	20·3	23·2
800	1·6	3·3	4·9	6·6	8·2	9·9	11·5	13·2	14·8	16·5	19·8	23·1	26·4
900	1·8	3·7	5·6	7·4	9·3	11·1	13·0	14·8	16·7	18·6	22·3	26·0	29·7
1000	2·0	4·1	6·2	8·3	10·6	12·4	14·5	16·5	18·6	20·7	25·0	29·0	33·0
1100	2·3	4·6	6·8	9·1	11·4	13·7	16·0	18·2	20·5	22·8	27·4	32·0	36·5
1200	2·5	5·0	7·4	9·9	12·4	14·9	17·4	19·8	22·4	24·8	29·8	34·7	39·7
1300	2·7	5·4	8·1	10·7	13·4	16·1	18·8	21·5	24·2	26·9	32·3	37·7	43·1
1400	2·9	5·8	8·7	11·6	14·5	17·4	20·3	23·2	26·1	29·0	34·8	40·7	46·4
1500	3·1	6·2	9·3	12·4	15·5	18·7	21·7	24·8	28·0	31·1	37·3	43·5	50·0
1600	3·3	6·6	9·9	13·2	16·5	19·8	23·2	26·5	29·8	33·1	39·8	46·4	53·0
1700	3·5	7·0	10·5	14·1	17·6	21·1	24·6	28·1	31·7	35·2	42·3	49·3	56·3
1800	3·7	7·4	11·2	14·9	18·7	22·4	26·1	29·8	33·6	37·3	44·7	52·2	59·7
1900	3·9	7·9	11·8	15·7	19·7	23·6	27·6	31·5	35·5	39·4	47·3	55·2	63·0
2000	4·1	8·3	12·4	16·5	20·7	25·0	29·0	33·1	37·3	41·4	49·6	58·0	66·2

Precautions to be taken to secure Good Driving.—If belts are to last a reasonable time, the following precautions should be taken, few of which receive proper attention on most oil properties: A long drive is an essential feature for successful driving, for the belt need not be so tightly stretched as in short drives, and the consequent "sag," due to weight and drive, gives a larger surface of contact with the driving-pulleys. The pulleys on the engine and drum must be absolutely truly fixed, *i.e.*, a line stretched from pulley to pulley must exactly touch the two edges of each pulley, and the drive must be arranged so that the pull takes place as in diagram A, and not as in diagram B.

In the former case, the weight of the belt assists the driving power by increasing the surface of contact, but in the latter the "sag" reduces the value of the drive by reducing the contact. The faces of the pulleys in such slow-speed drives must be well rounded, fully $\frac{1}{4}$ inch being allowed on the usual engine and bailing-drum pulleys. The rounding of the faces of pulleys was rarely executed until a few years ago, and it is scarcely to be wondered at that difficulties were experienced in keeping the belts from falling off without being unnecessarily stretched. Formerly, most of the steam-engines were either unprovided with fly-wheels or fitted with such ridiculously light ones that no practical result followed their employment on such powerful engines; but it is now more usual to fix heavy fly-wheels, from 6 to 6·5 feet diameter, and weighing 60 to 80 poods. Even in double-cylinder engines the drive is not steady without the attachment of heavy fly-wheels, and at each of the four dead-centres the belts are given a violent jerk, which causes them to oscillate and produce a powerful, unnatural tension which leads to frequent breakage.

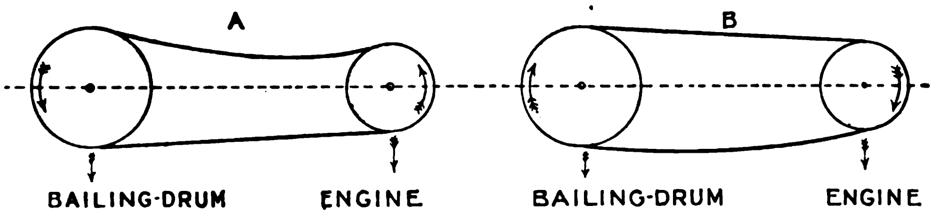

Fig. 92.—Belt Driving.

A. Correct way of driving. B. Incorrect way of driving.

Where electric motors are employed for bailing which run at a velocity of 700 revolutions a minute, in some cases it has been found advisable to fix a fly-wheel on the counter-shaft to minimize the momentary strain which is flung upon the transmitting belt when the bailing drum is thrown into gear. In any case, there is a great strain suddenly imparted to the belting when putting the bailing drum into action; but in the case of a steam-engine, the speed of the engine is generally very low at the moment, and the steam is only fully admitted after the connection is made.

One of the most important factors that decides the life of a belt is the fastening, lacing, or jointing, and upon the manner in which this is executed depends largely the future working.

The general manner of connecting hair-belting is to overlap the two extremities of the belt, and insert a number of small bolts fitted with countersunk heads, which lie flush with the working face of the belting, and are tightened by means of a nut working against a washer on the outer edge. For the purpose of inserting the bolts small holes are pierced in the belt, but care must be taken that the fibres are only forced aside, and not cut asunder by any sharp form of punch, or by driving the bolts through a too small hole.

The objections to the ordinary stocked bolts are—

(1) The bolts often revolve when the nuts are tightened up, and cannot therefore be firmly connected.

(2) They are frequently drawn completely through the belting, and rendered useless, besides damaging the belt.

If the bolt-heads are made hexagonal or square, and roughened washers are used on the outside edge, the objections may be partially overcome; but bolts are, even then, far from satisfactory. Tompkins' patent belt-fastener is one of the best connectors yet introduced for joining camel-hair belting, and consists of a bolt, provided with a countersunk head, fitted with two protruding spikes which enter the belting and prevent the bolt from revolving when being tightened up; and on the outer surface of the belting a hollow, oval, malleable washer, offering a rim of about 1½-inch radius, passes over the bolt, and is drawn firmly into the belting by a nut pressing on its upper edge.

Wire Ropes.—Bailing on the Russian oil fields is always conducted by means of a steel-wire rope, and upon the construction of a suitable and durable kind much attention has been bestowed. The conditions under which bailing ropes work are so different from those usually attending the employment of a similar rope, that it is scarcely a wonder that those giving the most satisfactory results for ordinary duties elsewhere should be quite useless in the oil fields, and break up in a few months.

In order that the properties of various types of ropes may be understood, a short description will be given of the varieties of " lay " and peculiarities of construction, by which particular ends are attained. A wire rope is composed of a central core, around which are twisted a certain number (usually six) of strands, each strand being composed of a number of wires, but the wires of which the strands are made are twisted in the opposite direction to the twist of the strands forming the complete rope. It is quite indifferent whether a right-hand or a left-hand twist is given to the strands, but it is advisable to keep to one or the other form, otherwise there is difficulty in splicing the two kinds of ropes together.

In English practice, a right-hand twist is that which is given to a rope when twisted in the direction in which the hands of a watch turn round; but in Russia, the opposite direction is usually termed a right-hand twist, the users of the latter system of denomination looking upon the strands of the rope as the threads of a screw, which are either left- or right-handed. When speaking, therefore, of a right- or left-handed twisted rope, care must be taken to ascertain clearly which direction is meant.

Flexibility is imparted to a wire rope either by the use of a hemp core, or by the employment of a larger number of finer wires in the separate strands, and inflexibility is secured either by fixing an iron or steel core, or using a coarser quality of steel in the preparations of the strands. The gauge of wire in one particular size of rope is, however, decided by the diameter of the latter, and the extent of flexibility or inflexibility that can be imparted is limited to certain extremes in each size.

The actual weight to be supported by the rope in bailing is so small compared with the tensile strengths of those supplied, that this need scarcely be brought into the subject of discussion, for whilst the greatest weight of a bailer full of oil does not exceed 1 ton, the tensile strength of only a ⅜-inch rope is about 4 tons. The life of a bailing rope is dependent upon other treatment of a special kind to which it is subjected, and which has led some of the best quality steel-wire ropes to be discarded in favour of those of inferior quality which answer their purpose. The action of some firms in testing the tensile strengths of their ropes before bailing is, for the above-mentioned reasons, quite unnecessary, and it is possible that many of the best ropes for bailing would not possess a high tensile value.

In an ordinary well of a diameter of 12 inches or more, which has been bored perfectly vertical, it is observed, after a few weeks' bailing, that the portion of the rope near the bailer begins to show signs of breaking up, and, to prevent an accident, the spoiled part, amounting to 60 or 70 feet, must be cut off. That the damage sustained is not due to the passage of the rope over the pulley and drum, is proved by examining the remainder of the rope, which has also had the same work, and which will be found to be free from any serious signs of wear.

The destruction of the rope at this part is apparently due to the lowering of the bailers through the empty portion of the bore-hole at a very high velocity, and the subsequent entanglement of the spare rope unconsciously let out when the surface of the oil has been reached. The only means the operator has of knowing when the bailer reaches the oil is by the noise of the blow when the surface of the liquid is struck, and a slackness transmitted to the rope; but as the bailer takes quite a perceptible time to fill and sink into the fluid, from 30 to 60 feet of slack rope are each time forced into a knotted mass by the momentum gained during its rapid descent, before the attendant is apprised, the brake applied, and its impetus checked. This not only leads to a constant severe bending and unbending action, repeated at rapid intervals, but it encourages the formation of knots and kinks, which produce a more disastrous effect on account of the jerk to which the rope is subjected as the slack part is taken up. The friction of the rope against the sides of the iron well casing, when it is slackened, rapidly abrades the small wires composing the strands, and produces an effect which never takes place so long as the rope is kept taut, and runs in the centre of the well.

It is difficult to say which of the above actions has the most destructive influence upon the rope, as it depends upon the construction and the quality of steel used, but a frequent, irregular coiling of the rope in varying circles of small radii, followed by the violent jerk as the bailer descends rapidly in the liquid after filling, must have a detrimental effect upon any rope by constant repetition, and must soon deprive the steel of its temper. The abrasive effect is clearly seen on all ropes after a few weeks' work in normal wells, but is more prominently exhibited in those of small diameter, and this action prevents the employment of flexible ropes, constructed of finer wires, which would better withstand the coiling into small circles. The abrasion is sufficient to condemn flexible ropes of whatever quality, and although quite unsuitable in all other respects, ⅝-inch and ¾-inch ropes are used with strands formed of as large a gauge of steel as is admissible to secure some degree of flexibility. In wells of small diameter (6-inch, 8-inch, and 10-inch), the abrasion is more excessive on account of the swinging to which the rope is liable when descending at a high velocity, causing rapid wear of the strands; but if the well is slightly out of vertical, or the overhead bailing pulley not quite centrally fixed over the mouth of the well, the rubbing may cause the total destruction of the strands in a few days.

To minimize or prevent the rapid wear of steel-wire ropes, many means have been tried, but with only partly successful results. Thirty to fifty feet of light chain have been introduced between the bailer and the wire rope to take up the slack created at each descent; and although the rope was thereby saved, the chain was often entangled and occasionally broke. An equal length of hemp rope was tried, and this, although saving the wire rope, had to be frequently replaced on account of the rapid wear resulting. The difficulty could be largely overcome, and the life of wire rope increased from 50 to 70 per cent., if the attendants could be induced to exercise a little judgment; but as this seems to be quite impossible, automatic preventive measures have to be sought. If a bonus is given to the operator in proportion to the length of time the rope lasts, the output from the well suffers, as the men use unnecessary care, and will lower the bailer at a ridiculously slow speed the whole distance.

Several devices have been patented for attachment to the bailing drums, which cause a gong to be struck when the bailer is approaching the liquid; and if due regard is paid to the sound, a great deal may be saved in ropes. The control apparatus described in Chapter VIII., page 221, performs this operation automatically without the addition of other attachments.

In crooked wells, where bailing is the only means of raising the oil, old pieces of wire rope from other wells, which are not too badly damaged, may be spliced together, and these answer the purpose for a time if the bailer is not a large one. Ropes in such wells may be to some extent protected by binding old wire round at intervals, and forming knots at the part of the rope which will pass through the curved portion of the bore-hole. Such swellings pass with freedom over the pulley and drum, and will preserve a rope for some time, if periodically inspected and replaced where needful.

From the explanations given, it is seen that $\frac{3}{8}$-inch and $\frac{1}{2}$-inch wire ropes, which would perform the actual work with ease, are prohibitive solely on account of the fine-gauge wires which alone can be plaited for such sizes. The rope, therefore, which gives the best local results is the one in which the strands are composed of the largest gauge and hardest quality of steel possible to retain sufficient flexibility to pass over a circle of a radius of 2 feet. Bailing ropes are always $\frac{5}{8}$-inch to $\frac{3}{4}$-inch, and are sold in lengths of from 700 to 2500 feet, coiled on a wooden drum, from which they may be transferred direct to the bailing drum. A large amount of spare rope is always allowed for the periodical cutting off of damaged pieces. For boring purposes, ropes are used up to 2 inches diameter, and for pulley-blocks $1\frac{1}{4}$-inch and $1\frac{1}{2}$-inch steel ropes are commonly employed.

English wire ropes were for a long time in most popular demand, but there are now large numbers of German, Austrian, Russian, and Danish ropes in use from which it is difficult to make a choice. Wire ropes are made in Baku which equal foreign ones, and as any description can be made to order, and English steel is used in their manufacture, there is no great advantage in imported makes. The Baku Wire Rope and Cable Co. has erected in Baku very up-to-date works for manufacturing all classes of wire ropes, which compare with any that can be purchased from abroad.

Fishing for Lost Wire Ropes.—If a wire rope breaks, and part is left in the bore-hole, or if, as sometimes happens, the rope becomes detached from the drum, or falls during a fire, it has to be fished up by means of special instruments which are kept always at hand for the purpose. They are of different forms, and are lowered on a new rope from the bailing drum to where the lost rope lies coiled up in the casing. Fig. 55, page 222, Chapter VIII., shows some of the common forms employed, and if one of these is chosen which suits the size of the well, and it is raised and lowered a few times above the lost rope, one or more of the fingers usually grasps the rope firmly. A lost wire rope generally coils itself into such a fantastic shape on falling that a plain hook rarely fails to entangle itself in the mass and secure a firm hold, but when the hook is emerging from the bore-hole with the rope, an examination should be made of the hold, and, if of an unsafe character, it should be assisted by binding with hemp rope. Unless this precaution is taken, the entangled rope often flies out and untwists when raised from the confined space of the tubes, becomes disengaged from the hook, and falls back into the well. If one type of fishing-hook fails to secure a grip after repeated trials, it must be replaced by another form; but in whatever manner the rope is fished up, it is rarely possible to use the whole again, owing to the kinks and knots which have formed.

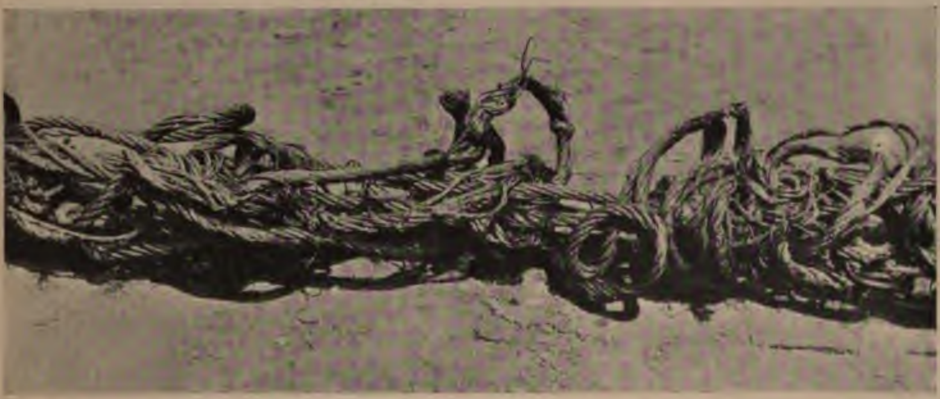

Fig. 93.—Wire Rope recovered from Baku Oil Well after having fallen over 1000 Feet.

Fig. 93 shows a wire rope fished from a deep Baku well after having fallen from the surface.

APPENDIX A.

TABLE I.

SHOWING THE NUMBER AND DESIGNATION, THE AREA IN DESSIATINES AND SQUARE SAGENES, AND THE LESSEE'S NAME OF EACH PLOT UNDER EXPLOITATION IN THE SEVEN CLASSES OF PROPERTIES ON THE BAKU OIL FIELDS.

TABLE II.

LIST OF PROPERTIES LEASED FROM THE GOVERNMENT ON A ROYALTY BASIS, WITH NAME OF LESSEE, AMOUNT OF ROYALTY, AND MINIMUM ANNUAL PAYMENT.

TABLE III.

STATISTICS OF EACH SEPARATE PROPERTY IN THE BAKU AND GROSNY OIL FIELDS.

Giving number of wells in exploitation.
Production of oil annually, in thousands of poods.
Average production per well, in thousands of poods.
Average depth of producing wells.
Maximum depth of wells.
Minimum depth of wells.

NOTE.—*The properties mentioned in this Appendix will be found on the loose large-scale map issued with this book.*

APPENDIX B.

EXTRACT FROM OFFICIAL RULES AND REGULATIONS RELATING TO THE RUSSIAN OIL INDUSTRY.

APPENDIX C.

USEFUL FIGURES AND TABLES.

NOTE.

In the back cover of this book will be found a large-scale coloured map of the Balakhany-Saboontchy-Romany-Zabrat and Bibi-Eibat oil fields, where properties mentioned in this Appendix are shown. The terms on which the plots are held are indicated by tints, fully explained in an attached key.

On the same map will be found a plan of the Apsheron Peninsula, showing the position of the various oil fields, and the area over which the oil-bearing strata are known to exist.

The Grosny properties are shown in the map facing page 130.

N.B.—These maps have been prepared from the latest Russian official maps, and have been brought up to date as far as possible by the Author.

APPENDIX A.

TABLE I.

I.—PROPERTIES THAT WERE IMPERIAL GRANTS TO DIFFERENT PEOPLE.

BALAKHANY.

Number of property.	Area.		Name of firm.	Number of property.	Area.		Name of firm
	Dessiatines.	Square sagenes.			Dessiatines.	Square sagenes.	
1	10		Caucasian Oil Co.	9	3		Grosberg.
2	2		Eastern Oil Co.	10	2		“Sinai” Co.
„	3		Tiflis Co.	„	3		“Faros” Co.
3	2		Adamoff, Alex.	11	1		Mantasheff and Co.
„	3		Amilakvari.	„	2		Nobel Bros.
„	5		Mantasheff and Co.	12	4		Baku-Russian Oil Co.
4	6		Adamoff, I. D.	„	1		St. Petersburg-Baku Oil Co.
„	4		Schibaieff and Co.	13	2	1200	Mantasheff and Co.
5	10		Nobel Bros.	„	2	1200	Zatouroff and Co.
6		2151	Balakhany Oil Co.	14	1	2000	“Kavkas” Co.
„	1	600	Galperin and Co.	15	1		Soombatoff.
„		2241	Galperin, I. G.	16	1		Kholiro.
„		2020	“Gokhtan” Co.	17	1		European Petroleum Co.
„	4		Caspian and Black Sea Co.	„	1		Kolesnikoff Bros.
„	2	187	Lazareff Bros.	18	2		Schibaieff Petroleum Co.
7	5		“Petrol” Co.	19	1		European Petroleum Co.
8	5		Balakhany Oil Co.				

II.—GOVERNMENT LANDS LEASED ON A ROYALTY BASIS, WITH A MINIMUM ANNUAL PAYMENT.

BALAKHANY.

2 B	3	1160	Benkendorf and Co.	11 B	2	2070	Nabatoff Bros. and Co.
3 B	4	580	Caucasian Oil Co.	12 B	6	2180	Balakhany Syndicate.
4 B	4	2295	Benkendorf and Co.	13 B	4	1130	Baku-Russian Oil Co.
6 B	4	2030	Arafeloff and Co.	15 B	4	100	Oosienoff Alifa, Khan.
7 B	4	1420	Volga-Caspian Oil Co.	17 B	5	810	Kalantaroff.
8 B	5	480	Gukasoff, P. O.	18 B	6	290	“Sever” Co.
9 B	1	1610	Akopoff and Adamoff.	19 B	5	200	“Kasbek” Co.
„	1		“Aragats” Co.	20 B	4	366	„ „
„	1		“Orion” Co.	21 B	3	1300	Kolesnikoff Bros.
10 B	4	1940	Schushin Oil Co.	22 B	3	1400	Nobel.
11 B	1		California Co.	23 B	5	2100	„

SABOONTCHY.

Number of property.	Area.		Name of firm.	Number of property.	Area.		Name of firm.
	Dessiatines.	Square sagenes.			Dessiatines.	Square sagenes.	
2 C	5	1550	"Vorotan" Co. and Ter-Makaroff.	22 C	2	1500	Nobel Bros.
				23 C	3	1200	Musa Nagieff.
3 C	5	700	Caspian Co.	24 C	2	960	Nobel Bros.
5 C	8	765	"Aramazd" Co.	26 C	1	870	Baku Oil and Trading Co.
13 C	2	160	European Petroleum Co.				
14 C	3	2020	Caspian and Black Sea Co.	29 C	1	1500	Nobel Bros.
15 C	2	1120	" " "	30 C	1	2080	" "
17 C	4	1540	Nobel Bros.	31 C	2	1500	" "
18 C	4	470	" "	32 C	2	2020	" "
20 C	1	1560	" "	33 C	2	1810	" "

ROMANY.

6 P	1	2330	Polak, T. D.	27 P	4	1690	Caspian and Black Sea Co.

BIBI-EIBAT.

1 B-E	4	1070	"Shakta" Co.	26 B-E	7	890	Khatisoff and Kandjuntseff.
2 B-E	4	1400	Bibi-Ebat Oil Co.	27 B-E	6	1557	Markaryants.
3 B-E	5	760	Caspian and Black Sea Co.	45 B-E	4	906	"Bibi-Eibat" Oil Co.
4 B-E	3	1670	Russian United Oil Co.	46 B-E	3	1980	Baku Oil Co.
5 B-E	4	200	St. Petersburg Oil Co.	47 B-E	3	1980	"Naftalansk" Oil Co.
6 B-E	3	2340	Baku Oil Co.	48 B-E	4	885	"Bibi-Eibat" Oil Co.
7 B-E	3	1150	Ogoolevich.	49 B-E	3	1130	Naftalansk Oil Co.
11 B-E	3	1960	Russian-Bibi-Eibat Oil Co.	50 B-E	3	1980	Bibi-Eibat Oil Co.
				51 B-E	3	1980	Nabatoff Bros., Partners and Co.
14 B-E	6	1640	"Schikhoff" Oil and Trading Co.	52 B-E	3	1370	Miloff and Tairoff.
15 B-E	7	1743	"Schikhoff" Oil and Trading Co.	54 B-E	5	165	Tiflis Co.
				55 B-E	5	617	Trading House, Kalantaroff and Co.
16 B-E	8	840	Balakhany Oil Co.				
17 B-E	8	1810	"Bibi-Eibat" Oil Co.	56 B-E	4	1098	Baku-Russian Oil Co.
25 B-E	7	1584	Pitoeff and Co.	57 B-E	5	2320	Mantasheff and Co.

III.—GOVERNMENT LANDS LEASED WITHOUT AUCTION, AT A ROYALTY.

BALAKHANY.

1 B	5	1600	Nobel Bros.				

SABOONTCHY.

Number of property.	Area.		Name of firm.	Number of property.	Area.		Name of firm.
	Dessiatines.	Square sagenes.			Dessiatines.	Square sagenes.	
35 C	1	19	Tumaieff and Co.	134		1370	Caspian Co.
36 C		1894	Baku-Russian Oil Co.	173	1	190	" "
37 C		765	Russian Oil Co.	175		836	" "
38 C		1905	Arshaluis Co.	176		1471	" "
39 C		1250	Tumaieff Bros.	191		433	"Kama."
40 C	2	148	Adamoff, A. I.	192		393	"Bakht" Co.
41 C	1	1968	"Vorotan" Co.	194		954	" "
42 C		960	Tumaieff and Co.	214		675	Mikirtoomoff.
13	1	887	Caspian Co.*	283		465	Caspian Co.
76		2277	Russian Oil Co.	297		937	"Tamara."
100		2156	Nobel Bros.	306		185	"Bakht" Co.
117		665	" "	155	1	1550	Nobel Bros.
118		665	" "	218		584	" "
154		1118	" "	101	1	1800	Osribekoff.

* Now renumbered to No. 111 Saboontchy, to distinguish from other Plot 13 in the same district.

ROMANY.

26 P		1200	Mantasheff and Co.	55	1	600	Caspian and Black Sea Co.
19 P		1000	Moscow Caucasian Oil Co.	20 P		500	Moscow Caucasian Oil Co.

IV.—GOVERNMENT PROPERTIES RENTED IN ACCORDANCE WITH A LAW ISSUED FEBRUARY 1, 1872, AT A RATE OF 10 ROUBLES PER DESSIATINE PER ANNUM.

I.	10		Baku Oil Co.	X.	10		Mirzoeff Bros. and Co.
II.	10		" "	XI.	8		" " "
III.	8		Mirzoeff Bros. and Co.	"	2		Pitoeff and Co.
"	2		Bibi-Eibat Tiflis Co.	XII.	10		Apsheron Oil Co.
IV.	10		Baku Oil Co.	XIII.	1	1200	Vartanoff Bros.
V.	5	733	"Kavkas" Co.	"	2		Gagen, T. and E.
VI.	10		Baku Oil Co.	"	6	1200	"Soouchastniki" Co.
VII.	10		Russian Oil Co.	XIV.	10		Mantasheff and Co.
VIII.	10		Baku Oil Co.	XV.	10		Baku Oil Co.
IX.	10		Mirzoeff Bros. and Co.	XVII.	10		Benkendorf and Co.

SABOONTCHY.

V.		200	Nobel Bros.	XVI.		400	Nobel Bros.

BIBI-EIBAT.

XIX.	10		Russian Petroleum and Liquid Fuel Co.	XX.	9	2300	Zubaloff.

V.—GOVERNMENT LANDS RENTED BY VILLAGERS FOR A PERIOD AT A NOMINAL RENTAL.

BALAKHANY.

Number of property.	Area.		Name of firm.	Number of property.	Area.		Name of firm.
	Dessiatines.	Square sagenes.			Dessiatines.	Square sagenes.	
36	4	621	Nobel Bros.	158	2		Markaryants.
142	5	1200	Russian Oil Co.	159	1		„
143	2	1200	Tumaieff Bros.	221	3	720	Russian Oil Co.
144	1		"Korun" Co.	„	1		"Eraz II." Co.
145	1		First Russian Oil Co.	267	1	326	Musa Nagieff.
147	1		Boga-boga Co.	278		400	Zovianoff.
148	1		Karaund Oil Co.	279	1		Djabieff and Co.
149		1200	Kolmanoff and Co.	282	1		"Bakht" Co.
152		1200	Zatouroff and Co.	„	1		Ter-Kasparoff.
153	1		"Anand" Co.	„	2	800	Zovianoff Bros. and Co.
154		600	Balakhany-Saboontchy Oil Co.	344	1		Baku Oil and Trading Co.
				363		1200	Ter-Kasparoff.

BIBI-EIBAT.

(Since returned to Government and re-leased to former lessees at a royalty of 35 per cent.).

27	10	210	Nobel Bros.	36	3	1091	Baku-Russian Oil Co.
28	5	105	Caspian and Black Sea Co.	37	3	958	Mantasheff and Co.
29	4	358	„ „ „ „	38	3	1577	Schibaieff and Co.
„		2092	Schibaieff and Co.				

VI.—FREEHOLD LANDS.

SABOONTCHY.

3		2000	"Nor-Masis."	14	1	2200	Mirzoeff Bros. and Co.
„		1995	Russian United Oil Co.	15	1	356	Adamoff, Ap.
4	4	1200	"Nor-Masis."	16		1000	Mantasheff and Co.
7	1	895	Pitoeff and Co.	„		2328	Popoff and Co.
8	1	2200	Booniatoff Bros.	17		1889	Antonoff.
9		577	Lazareff and Co.	„		1880	Balakhany Co.
„		577	Mnatsakanoff and Co.	„		300	"Vastak" Co.
„		2045	Relski.	„		711	Dadiani.
10		625	Akopoff, Aslan.	18		1314	Dochar.
„	1	610	Pitoeff and Co.	„		566	Tumaieff and Co.
11		820	Adamoff, A.	19	1	1960	„ „
„		750	Akopoff, Aslan.	20	15	2304	Baku Oil Co.
„		1690	Blazi.	21	1	1100	Nobel Bros.
„		500	Kaiser.	22		1125	Avakoff.
„	1	1320	Caspian and Black Sea Co.	„		1400	"Kavkas" Co.
„		600	"Loosnyak" Co.	„		500	Kvaristrem.
„		860	Nadjaroff.	„		500	Schumacher.
„		1500	Pogosoff.	24	1	1150	Ter-Akopoff Co.
12	2	555	"Gabur" Co.	25		1915	Krasilnikoff, I.
12 C	4		Russian Oil Co.	„		2008	Chernoneboff.
13	1	1280	Baku-Russian Oil Co.	26	6	1440	Caspian and Black Sea Co.
14	1	800	„ „ „	„		792	Leskevich.

SABOONTCHY—*continued.*

Number of property.	Area.		Name of firm.
	Dessiatines.	Square sagenes.	
27	1	1560	Chernoneboff.
28		1200	Adamoff, D.
„	1	1560	Ter-Akopoff Co.
29	1	1140	Soouchastniki " Co.
31	1	1410	Saboontchy Oil Co.
„		784	Sarookhanoff.
32		1065	Abiyants and Co.
„		1000	Caspian Co.
„		300	" Molot."
„		500	Mnatsakanoff.
33		1630	Krasilnikoff, R.
„		1582	Chernoneboff.
35		490	European Petroleum Co.
36		1590	Ter-Akopoff Co.
37	1	1440	European Petroleum Co.
38		484	„ „ „
„		766	Mantasheff and Co.
39		280	European Petroleum Co.
40	4	1380	Baku Oil Co.
41	1	360	Nobel Bros.
42	5	1200	Mirzoeff Bros. and Co.
43	1	1749	Nobel Bros.
44		1400	Zovianoff Bros. and Co.
45		2060	Caspian Co.
46	1	246	Baku-Russian Oil Co.
47		643	Kolmanoff and Nazaroff.
„		321	Mantasheff and Co.
„		643	Relski.
„		964	Saboontchy Oil Co.
48		481	Baku-Russian Oil Co.
„		1450	Mantasheff and Co.
49		1490	European Petroleum Co.
50	2	1200	Mantasheff and Co.
„	9	1965	Mirzoeff Bros. and Co.
„	4	75	Pitoeff and Co.
51		760	Nobel Bros.
52	2	960	„ „
53	1	340	Saboontchy Oil Co.
54		511	Manafoff.
„		1800	Nobel Bros.
55		1800	„ „
56		1868	Baku-Russian Oil Co.
„		1536	" Bakht " Co.
„		1400	" Kama " (Mitrofanoff).
„		800	Mangasaroff.
57	2	360	Ter-Akopoff Co.
58		2283	Krasilnikoff Bros.
„		2330	Krasilnikoff, N.
59	1	120	Pitoeff and Co.
60	2	200	Nobel Bros.
61	1	260	Ter-Akopoff Co.
62	1		" Votan " Co.
63		1407	" Maigooli " Co.
64	2		Russian Oil Co.
67	1	1270	Nobel Bros.
68		1271	Astrakhan Co.
68		600	" Vanand " Co.
„		450	Koosis and Teofilaktos.
„	1	2143	Nobel Bros.
„		1271	" Saboontchy Co.
„		1643	Schibaieff and Co.
69	1		Baku-Russian Oil Co.
„	1		Caspian and Black Sea Co.
„	1		Kvaristrem and Co.
70	1	305	„ „
„	1	60	Shagidanoff and Co.
71	1	860	Baku Oil Co.
72		600	Egiazaroff.
„		1060	" Neft " Co.
„		1109	Nobel Bros.
„		300	" Tamara " (Shagidanoff).
73	1	20	Russian Oil Co.
„			Ter-Akopoff Co.
75	1	190	Dembot Bros.
76	18	1067	Caspian and Black Sea Co.
77	1	565	Baku-Russian Oil Co.
83	1	20	Kocharoff and Co.
130	1	1320	Schibaieff, E. C.
137		1890	" Radoga " Co.
140		2330	Russian Oil Co.
142		370	" Looch " Co.
146	1		Nobel Bros.
„		1680	" Shirvan " Co.
147		1590	„ „
148		215	" Taron " Co.
151	1	435	" Kavkas " Co.
152		1060	Schibaieff Co.
153		2090	„ „
„		1445	St. Petersburg - Baku Oil Co.
„		1775	Zatouroff, A.
157	1	930	Moortooza Mukhtaroff.
158	3	1080	" Soouchastniki " Co.
159		200	Aslanoff.
„		1680	" Russia " Co.
160		474	Nobel Bros.
161		2364	Baku-Russian Oil Co.
162		1040	Balakhany Co.
163	1	510	Baku-Russian Oil Co.
164		740	Nobel Bros.
165		936	Tumaieff and Co.
166		510	" Karaund " Co.
„		100	Mirkirtoomoff and Co.
„		1000	Tumaieff Bros.
„		730	Tumaieff and Co.
167	2	2320	Caspian Co.
168		820	Nobel Bros.
169	1	1145	European Petroleum Co.
„		1530	Caspian Co.
170		800	Baku-Russian Oil Co.
„		1200	" Minerva " Co.
„		400	Tumaieff and Co.

SAROONTCHY—*continued.*

Number of property.	Area.		Name of firm.	Number of property.	Area.		Name of firm.
	Dessiatines.	Square sagenes.			Dessiatines.	Square sagenes.	
171		1820	Nobel Bros.	V.		770	Baku-Russian Oil Co.
172	1	2040	„ „	„		420	Dadasheff.
„		450	Tumaieff and Co.	„	1	720	Melikoff, A. C., and Co.
173		1000	" Arshaluis II." Co.	„		1020	Mirza-Avakoff and Karabekoff.
„	1	675	Baku-Russian Oil Co.				
174		2129	Caspian Co.	„		1200	Nobel Bros.
175		1955	" Astgik I." Co.	„		400	Tairoff.
„		1226	Ashourbekoff.	XVI.		1028	Akopoff, Aslan.
„	1	810	European Petroleum Co.	„	1	1824	European Petroleum Co.
„		772	Mantasheff and Co.	„		1150	Gagen and Ter-Akopoff.
177		2160	Caspian Co.	„		225	" Eraz " Co.
178	1	385	Nobel Bros.	„		880	" Islam " Co.
179		1450	Schibaieff and Co.	„	1	1830	Krasilnikoff, N.
180		1360	Russian Oil Co.	„		910	Manafoff.
181	1	1230	Caspian and Black Sea Co.	„	1	1400	Mirzoeff Bros. and Co.
V.		1060	" Ararat " Co.	„	1	900	Nobel Bros.
„	1	1128	Baku Oil Co.	„	1	1453	Ter-Akopoff Co.

ROMANY.

23	1	1120	Nobel Bros.	32		831	Caspian Co.
25		1560	Mantasheff and Co.	„		831	Nobel Bros.
26		680	Nobel Bros.	33		528	Krasilnikoff Bros. and Co.
28		1260	Mantasheff and Co.	35		350	Mantasheff and Co.
29	1	600	Caspian Co.	40		1884	Nobel Bros.
30		364	Kalantaroff.	42	1	1800	Musa Nagieff.
31		215	Nobel Bros.	54	3	480	" Sevan " Co.

VII.—LANDS UNDER DISPUTE WITH THE GOVERNMENT.

ROMANY.

33	1	2180	European Petroleum Co.	76		1275	Pitoeff and Co.
36	2		Mantasheff and Co.	95	1	479	" Sunik " Co.
38	12	959	Caspian and Black Sea Co.	96		1000	Caspian and Black Sea Co.
40	1		Caspian Co.				
42	1	26	Baku-Russian Oil Co.	97		1254	" Arax."
43		900	Russian Oil Co.	102	1	1600	Schibaieff and Co.
44		1800	" Arax."	103	2	1870	Mantasheff and Co.
45		1890	Mantasheff and Co.	107	5	905	Asadulaieff.
46	3	2082	Caspian and Black Sea Co.	„	2	1352	Caspian and Black Sea Co.
47		2318	Melikoff, A. C., and Co.	„	2	1352	Musa Nagieff.
48	3	2080	Caspian Co.	140	6		Gadjinski.
58	2	1167	Mantasheff and Co.	„	4		Nobel Bros.

The list below gives all the Government plots based on a royalty basis, with the name of the lessee, the amount of royalty, and the extent of the minimum annual payment due to the Treasury:—

TABLE II.

LIST OF PROPERTIES LEASED FROM THE GOVERNMENT ON A ROYALTY BASIS, WITH NAME OF LESSEE, AMOUNT OF ROYALTY, AND MINIMUM ANNUAL PAYMENT.

BALAKHANY.

Number and description of property.	Name of lessee.	Royalty per pood in copecks.	Minimum annual payment in roubles.	Number and description of property.	Name of lessee.	Royalty per pood in copecks.	Minimum annual payment in roubles.
1 B	Nobel Bros.	1	10,000	13 B	Baku-Russian Oil Co.	0·75	6,750
2 B	Benkendorf and Co.	$2\frac{1}{8}$	14,785	14 B	Shushin Co.	0·877	7,612
3 B	Caucasian Oil Co.	$1\frac{17}{32}$	8,951	15 B	Alifa-Khan Oosienoff.	$1\frac{1}{16}$	8,606
4 B	Benkendorf and Co.	2·51	24,849	17 B	Kalantaroff, M. A.	$\frac{7}{8}$	9,362
6 B	Arafeloff and Co.	2·77	26,869	18 B	"Sever" Co.	3·52	42,944
7 B	Volga-Caspian Oil Co.	2·17	19,964	19 B	"Kasbek" Co.	3·08	41,416
8 B	Gukasoff, P. O. ("Zabava").	2·08	21,632	20 B	,, ,,	2·77	22,991
				21 B	Kolesnikoff Bros.	$2\frac{11}{32}$	16,640
9 B	Akopoff and Adamoff, etc.*	$2\frac{3}{32}$	16,653	22 B	Nobel Bros.	1·8	11,960
				23 B	,, ,,	1·9	22,420
10 B	Shushin Co.	2·75	26,400	25 B	Khatisoff, K. E.	3·682	45,656
11 B	"California" Co., etc.†	$2\frac{7}{16}$	18,287	38 B	Bastamoff, D. S.	1·57	2,184
12 B	Balakhany Syndicate.	1·02	14,076	46 B	Indman, F. K.	1·77	708

*** Also "Aragats" Co. and Orion Co.** **† Also Nabatoff Bros. and Co.**

SABOONTCHY.

2 C	"Vorotan" and Ter-Makaroff.	$2\frac{7}{8}$	48,875	35 C	Tumaieff and Co.	2·1	4,433
				36 C	Baku - Russian Oil Co.	2·1	6,351
3 C	Caspian Co.	2·16	34,560				
5 C	"Aramazd" Co.	4·02	111,354	37 C	Russian Oil Co.	1·56	4,687
13 C	European Petroleum Co.	3·25	26,975	38 C	"Arshaluis II." Co.	3·0	9,540
				39 C	Tumaieff Bros.	3·25	6,825
14 C	Caspian and Black Sea Co.	3·27	50,358	40 C	Adamoff, A. E.	4·02	27,594
				41 C	"Vorotan" Co.	4·0	29,600
15 C	Caspian and Black Sea Co.	3·31	32,769	42 C	Tumaieff and Co.	4·0	6,400
				13	Caspian Co.	4·25	23,205
17 C	Nobel Bros.	2·6	48,360	76	Russian Oil Co.	4·25	15,914
18 C	,, ,,	2·6	43,680	100	Nobel Bros.	4·25	15,274
20 C	,, ,,	2·1	13,860	134	Caspian Co.	4·25	9,189
22 C	,, ,,	2·6	27,300	173	,, ,,	4·25	18,345
23 C	Nagieff, Musa.	3·675	51,450	175	,, ,,	4·25	5,875
24 C	Nobel Bros.	0·9	8,640	176	,, ,,	4·25	10,418
26 C	Baku Oil and Trading Co.	4·8	17,180	191	"Kama."	4·25	3,067
				192	"Bakht" Co.	4·25	2,787
29 C	Nobel Bros.	2·9	18,850	194	,, ,,	4·25	6,765
30 C	,, ,,	3·05	22,875	214	Mikirtoomoff.	4·25	4,781
31 C	,, ,,	2·9	30,450	283	Caspian Co.	4·25	3,118
32 C	,, ,,	3·06	34,770	297	"Tamara."	4·25	6,666
33 C	,, ,,	3·05	33,855	306	"Bakht" Co.	4·25	1,310

TABLE III.

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

BALAKHANY.

Productions of Oil in Thousands of Poods; Depths of Wells in *Sagenes*.

Property No. 1 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897	5	1,974	394	89·8	109	79
1898	4	1,374	343	92·7	109	82
1899	4	969	242	103·5	119	82
1900	5	969	193	109·4	133	82
1901	5	671	134	109·4	133	82
1902	6	473	79	123·0	193	96
1903						
1904						
1905						

Property No. 2 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	2	77	38	227·0	228	226
1900	1	112	112	228·0	228	228
1901	4	250	62	179·7	228	130
1902	2	274	137	227·0	228	226
1903						
1904						
1905						

Property No. 3 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898						
1899	3	384	116	164·6	221	64
1900	6	1,032	172	200·5	223	115
1901	6	1,894	315	216·3	223	209
1902	7	1,476	211	214·4	223	209
1903						
1904						
1905						

Property No. 4 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897						
1898						
1899	2	259	129	103·0	107	99
1900	6	884	147	118·1	201	49
1901	10	1,272	127	113·7	207	49
1902	9	1,301	145	117·5	207	49
1903						
1904						
1905						

Property No. 6 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	1	194	194	135·0	135	135
1900	4	297	274	175·2	199	135
1901	4	1,889	472	197·5	203	191
1902	5	1,258	252	192·4	203	167
1903						
1904						
1905						

Property No. 7 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898						
1899	1	120	120	141·0	141	141
1900	1	224	224	198·0	198	198
1901	2	182	91	209·0	220	198
1902	3	724	241	208·0	220	198
1903						
1904						
1905						

Property No. 8 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897						
1898						
1899	2	426	213	146·5	156	137
1900	5	2,795	558	146·4	156	137
1901	9	4,584	509	156·2	189	137
1902	8	2,371	296	175·6	221	148
1903						
1904						
1905						

Property No. 9 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	6	1,149	191	119·3	128	110
1900	8	2,470	308	134·0	151	120
1901	8	2,293	286	135·2	151	120
1902	4	1,244	311	149·0	154	142
1903						
1904						
1905						

Property No. 10 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898	2	13	6			
1899	12	1,271	105	104·0	140	71
1900	8	785	98	116·5	132	71
1901	5	746	149	101·2	127	71
1902	8	776	97	98·4	133	71
1903						
1904						
1905						

Property No. 17 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897	4	507	126	92·2	107	79
1898	6	1,567	261	88·3	107	75
1899	7	1,355	193	86·1	107	75
1900	8	1,529	191	84·8	107	75
1901	9	1,292	143	82·6	98	74
1902	10	1,532	153	83·9	98	74
1903						
1904						
1905						

Property No. 18 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	3	73	24	106·0	110	102
1900						
1901						
1902						
1903						
1904						
1905						

Property No. 21 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898	2	87	43	108·8	129	88
1899	3	646	215	106·3	129	88
1900	5	926	185	108·2	131	88
1901	6	1,056	176	108·3	137	88
1902	6	1,093	183	108·3	137	88
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY. BALAKHANY—(*contd.*)

Property No. 22 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	2	579	289	122·0	125	119
1900	4	956	239	124·0	137	115
1901	5	760	152	124·4	137	115
1902	4	688	172	124·0	137	115
1903						
1904						
1905						

Property No. 23 B.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898	2	217	108	129·5	140	119
1899	2	554	277	129·5	140	119
1900	2	110	55	129·5	140	119
1901	3	475	158	127·6	140	117
1902	5	688	138	134·8	152	118
1903						
1904						
1905						

Property No. 36.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	1	49	49	157·0	157	157
1900	2	121	60	133·0	157	109
1901	2	185	92	133·0	157	109
1902	2	132	66	133·0	157	109
1903						
1904						
1905						

Property No. 143.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	2	123	61	99·5	107	92
1900	1	18	18	92·0	92	92
1901						
1902						
1903						
1904						
1905						

Property No. 144.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897	2	411	205	104·6	114	96
1898	3	706	235	107·8	114	96
1899	3	362	120	111·6	114	108
1900	4	378	94	115·0	125	108
1901	3	245	81	111·6	114	108
1902	3	218	73	111·7	114	108
1903						
1904						
1905						

Property No. 145.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898	4	616	154	121·7	173	106
1899	5	284	56	122·8	173	106
1900	4	218	54	126·5	173	106
1901	5	221	44	123·8	173	106
1902	4	401	100	115·2	127	106
1903						
1904						
1905						

Property No. 147.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	2	165	82	162·0	164	160
1900	1	17	17	160·0	160	160
1901						
1902						
1903						
1904						
1905						

Property No. 148.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898						
1899	3	181	60	104·3	113	94
1900	3	6	2	95·0	113	78
1901						
1902						
1903						
1904						
1905						

Property No. 152.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899						
1900						
1901	1	183	183	190·0	190	190
1902						
1903						
1904						
1905						

Property No. 153.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	1	36	36	87·0	87	87
1900	1	39	39	111·0	111	111
1901						
1902						
1903						
1904						
1905						

Property No. 154.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1897						
1898						
1899						
1900	1	611	611	146·0	146	146
1901	1	415	415	146·0	146	146
1902	2	737	369	146·5	147	146
1903						
1904						
1905						

Property No. 159.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898	1	26	26	104·0	104	104
1899	2	438	219	111·5	119	104
1900	5	331	66	128·2	140	104
1901	4	99	24	125·7	140	104
1902	2	64	32	136·5	140	123
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY. BALAKHANY—(*contd.*)

Year.	Property No. 221.						Property No. 2.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	1	124	124	214·0	214	214	5	459	91	147·0	166	133
1897	2	183	91	197·5	214	181	13	1,937	149	110·5	166	42
1898	1	1	1	214·0	214	214	18	2,976	165	128·3	167	42
1899	1	168	168	214·0	214	214	17	2,959	174	136·2	179	42
1900	1	183	183	214·0	214	214	20	3,420	171	138·8	179	42
1901	2	254	127	199·5	214	185	20	2,270	113	142·2	184	60
1902	1	209	209	185·0	185	185	14	1,526	109	154·9	215	103
1903												
1904												
1905												
	Property No. 278.						Property No. 3.					
1896							18	2,889	160	95·2	165	62
1897							26	6,867	264	91·9	165	37
1898	1	23	23	81·0	81	81	30	4,68	156	79·2	131	37
1899	1	170	170	91·0	91	91	28	2,372	84	92·2	133	55
1900	1	121	121	91·0	91	91	29	1,882	62	105·5	179	72
1901	1	69	69	91·0	91	91	23	,558	67	96·4	142	72
1902							20	1,264	63	96·0	142	72
1903												
1904												
1905												
	Property No. 279.						Property No. 4.					
1896							17	1,174	69	97·2	137	70
1897	1	3	3	133·0	133	133	17	1,794	105	96·9	172	60
1898	3	1,373	457	109·3	130	95	23	2,973	129	93·6	172	60
1899	4	138	47	123·5	142	102	22	3,903	177	96·6	172	60
1900	2	78	39	112·5	123	102	23	4,272	185	101·3	172	60
1901	1	14	14	123·0	123	123	25	2,864	114	106·1	172	60
1902							27	2,462	91	105·7	172	60
1903												
1904												
1905												
	Property No. 282.						Property No. 5.					
1896							15	3,509	233	116·0	160	65
1897							16	4,056	253	107·2	131	66
1898	1	21	21	34·0	34	34	16	4,117	257	108·5	141	66
1899	5	384	76	75·6	120	20	16	3,752	234	105·7	128	66
1900	5	387	77	79·0	120	34	16	3,120	195	106·6	128	66
1901	5	269	53	79·0	120	34	20	3,144	157	109·9	131	66
1902	1	70	70	120·0	120	120	20	3,156	158	111·6	134	66
1903												
1904												
1905												
	Property No. 363.						Property No. 6.					
1896							28	5,180	185	114·2	160	60
1897							28	4,715	168	119·1	160	63
1898							33	5,341	161	126·7	160	63
1899							40	5,897	147	109·3	155	58
1900							43	4,968	115	111·2	173	60
1901	1	135	135	113·0	113	113	40	3,917	97	113·9	173	60
1902	2	123	61	110·0	113	107	30	2,798	93	119·8	214	70
1903												
1904												
1905												
	Property No. 1.						Property No. 7.					
1896	11	4,103	371	127·1	203	75	5	1,038	207	107·2	122	69
1897	14	3,010	215	137·8	208	75	5	1,093	218	99·8	122	69
1898	13	3,464	264	143·6	208	96	5	1,561	312	107·8	122	72
1899	15	4,895	326	143·2	208	96	14	2,220	158	107·2	122	72
1900	16	4,462	278	141·5	208	94	18	2,946	163	114·6	141	72
1901	17	4,488	263	146·2	208	96	18	1,897	105	117·8	156	72
1902	14	5,050	361	154·4	194	103	17	1,823	107	115·6	141	72
1903												
1904												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. BALAKHANY—(*contd.*)

Year.	Property No. 8.						Property No. 14.					
	Number of productive wells.	Production of oil	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	13	3,688	283	120·9	149	80	1	41	41	132·0	132	182
1897	11	3,446	313	117·4	140	82	2	95	47	114·7	132	97
1898	10	3,147	314	119·9	140	82	1	94	94	121·0	121	121
1899	14	3,212	229	115·5	140	64	3	240	80	97·0	128	71
1900	23	4,989	216	120·1	184	64	9	609	67	97·7	134	71
1901	23	3,641	158	116·2	152	64	11	974	88	96·6	138	71
1902	24	2,911	121	120·6	184	64	11	1,076	98	104·2	138	71
1903												
1904												
1905												
	Property No. 9.						Property No. 15.					
1896	5	1,781	356	121·2	130	100	3	184	61	88·3	95	84
1897	5	1,499	299	125·8	134	110	3	203	67	91·3	95	86
1898	5	785	157	127·5	138	110	3	105	35	78·6	96	65
1899	5	821	164	127·4	138	110	2	322	161	70·0	75	65
1900	8	706	88	121·1	138	95	2	446	223	70·0	75	65
1901	8	1,036	129	122·3	136	95	4	518	129	103·7	153	65
1902	8	778	97	122·4	136	95	4	653	163	103·7	153	65
1903												
1904												
1905												
	Property No. 10.						Property No. 16.					
1896	4	1,215	303	95·2	113	69	2	289	144	107·5	108	107
1897	5	1,014	202	108·8	138	88	2	341	170	107·5	108	107
1898	13	1,220	93	102·9	136	65	2	114	57	100·5	103	98
1809	17	3,371	198	120·8	179	76	2	167	83	100·5	103	98
1900	21	2,859	136	132·6	179	76	4	127	31	97·0	103	87
1901	19	2,671	140	138·0	179	76	4	182	45	97·0	103	87
1902	16	2,479	155	136·2	179	76	4	187	47	97·0	103	87
1903												
1904												
1905												
	Property No. 11.						Property No. 17.					
1896	5	1,088	217	114·2	135	90	8	1,702	212	112·5	139	78
1897	5	1,182	236	113·9	135	90	9	989	109	117·2	159	79
1898	6	440	73	111·6	135	90	9	1,242	138	119·8	159	79
1899	6	677	112	118·6	142	90	9	1,022	113	122·2	159	79
1900	6	878	146	119·3	142	90	12	1,361	113	125·0	159	69
1901	8	1,045	130	121·5	142	90	10	926	92	125·3	159	79
1902	9	998	111	125·0	142	90	7	773	110	118·0	146	79
1903												
1904												
1905												
	Property No. 12.						Property No. 18.					
1896	3	332	110	118·0	128	108	6	2,106	351	94·5	116	69
1897	5	754	150	135·2	165	108	9	2,220	246	91·8	116	82
1898	7	836	119	134·0	165	108	8	1,824	228	94·7	116	84
1899	7	787	112	134·0	165	108	10	1,469	146	100·2	140	82
1900	4	683	170	133·7	165	118	13	1,918	147	113·8	172	82
1901	11	1,181	107	105·8	165	77	14	2,008	143	110·5	156	82
1902	13	1,464	113	103·5	140	77	14	1,541	110	113·9	179	82
1903												
1904												
1905												
	Property No. 13.						Property No. 19.					
1896	1	51	51	35·0	35	35	3	459	153	117·6	130	96
1897	3	419	139	50·9	78	35	2	308	154	111·5	127	96
1898	13	3.184	244	90·7	129	34						
1899	18	3,240	180	105·8	137	67	1	0,9	0.9	96·0	96	96
1900	27	3,613	133	115·7	162	67	2	184	92	135·0	163	107
1901	26	3,032	116	121·5	166	73	1	5	5	167·0	167	167
1902	27	1,966	110	127·3	166	73						
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE GROUP.

BALAKHANY—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Group No. I.						**Group No. V.**					
1896	4	2,235	559	83·0	90	78	14	4,870	340	130·0	170	89
1897	6	2,839	473	88·0	98	78	19	4,563	240	133·8	198	89
1898	11	4,201	382	95·4	142	78	17	3,395	199	127·4	176	85
1899	15	3,070	204	96·6	142	78	22	3,450	156	124·5	208	85
1900	20	4,688	233	97·5	142	73	18	3,014	167	122·5	208	85
1901	25	4,099	163	99·7	142	73	22	2,461	111	118·6	150	89
1902	24	3,104	129	100·7	142	73	23	2,151	94	125·1	162	102
1903												
1904												
1905												
	Group No. II.						**Group No. VI.**					
1896	5	1,352	270	77·4	112	51	5	2,091	418	83·2	91	78
1897	7	2,593	370	87·6	112	51	7	1,310	187	89·4	109	78
1898	8	2,768	346	90·3	112	51	10	1,535	153	90·2	109	62
1899	10	2,628	262	92·9	113	51	9	1,640	182	92·6	109	62
1900	12	2,121	176	101·9	121	51	14	2,074	148	100·2	147	62
1901	11	2,239	203	123·1	198	87	15	1,986	132	105·2	147	62
1902	11	2,463	224	122·7	155	87	14	2,086	149	115·3	174	91
1903												
1904												
1905												
	Group No. III.						**Group No. VII.**					
1896	31	19,953	643	94·4	127	67	13	2,765	212	81·9	111	40
1897	42	18,279	435	102·9	129	81	19	4,109	216	89·4	116	48
1898	50	16,677	333	109·3	129	81	16	3,213	200	90·7	116	48
1899	50	12,717	254	109·3	143	81	19	2,809	147	92·3	118	48
1900	50	10,299	206	109·6	139	81	24	2,533	105	92·8	118	48
1901	51	8,206	160	113·4	135	81	20	1,788	89	97·7	144	48
1902	45	6,884	153	115·3	136	85	16	1,337	84	96·6	133	48
1903												
1904												
1905												
	Group No. IV.						**Group No. VIII.**					
1896	10	4,585	458	88·1	127	54	2	366	183	81·0	82	80
1897	17	5,181	304	96·9	127	65	2	166	83	81·0	82	80
1898	21	5,236	249	99·9	127	65	2	78	39	100·7	119	82
1899	27	5,524	204	104·0	146	65	3	70	23	115·3	133	82
1900	37	12,825	346	112·9	146	65	3	399	133	91·0	133	58
1901	37	12,136	328	121·8	149	65	5	550	110	90·0	133	53
1902	37	9,931	268	132·9	181	100	5	685	137	100·0	133	81
1903												
1904												
1905												

IONS FOR EACH SEPARATE GROUP. BALAKHANY—(*contd.*)

	oup No. IX.						Group No. XIII.					
		Producti	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	9	1,972	219	100·0	147	63	4	551	137	85·7	118	63
	9	968	107	97·3	121	62	5	746	149	79·2	87	63
	8	1,407	175	101·3	121	62	12	1,840	153	121·4	143	63
	10	1,921	192	99·2	121	62	16	3,866	242	102·0	145	63
	16	2,542	158	102·9	145	62	23	4,992	217	113·3	163	63
	18	3,708	205	113·3	173	62	31	6,387	206	117·3	163	68
	17	3,067	180	113·5	145	80	35	5,035	144	119·0	163	67

	Group No.						Group No. XIV.					
1896	1	99	99				4	670	167	100 0	122	94
7	3	331	110				7	2,999	428	100·9	126	54
8	4	1,023	255	[illegible]			14	3,392	242	101·7	122	54
9	7	1,136	162	93·5			16	2,792	174	112·5	217	54
1900	8	778	97	106·3			27	2,881	106	115·1	217	74
1901	8	552	69	106·3	[illegible]		22	1,710	77	107·5	131	74
1902							18	1,728	96	111·7	208	74
1903												
1904												
1905												

	Group No. XI.						Group No. XV.					
1896	1	19	19	120·0	120	120	15	4,724	315	89·7	146	67
1897	3	572	190	73·6	95	30	19	6,605	347	96·6	155	72
1898	10	4,994	499	68·5	121	30	22	5,213	236	88·2	108	72
1899	20	7,141	357	107·3	148	30	18	3,381	187	91·2	108	69
1900	23	2,446	107	115·2	156	81	26	4,947	190	105·5	132	74
1901	21	1,964	93	115·0	156	88	32	5,981	185	110·3	141	74
1902	17	1,663	98	110·9	156	85	30	4,216	141	118·7	167	77
1903												
1904												
1905												

	Group No. XII.						Group No. XVI.					
1896	10	3,267	326	85·9	100	71	19	7,708	405	92·2	161	28
1897	10	1,818	181	91·1	170	59	27	7,562	280	96·7	169	47
1898	12	1,853	154	121·4	202	38	24	7,159	298	99·6	169	71
1899	17	1,753	103	125·8	202	38	25	7,746	309	104·4	169	81
1900	15	1,835	122	114·7	193	38	30	6,500	216	102·8	179	72
1901	19	1,782	93	104·8	155	39	34	5,161	151	99·5	169	71
1902	21	1,557	74	117·1	203	59	34	5,756	169	102·6	169	76
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

SABOONTCHY.

Year.	**Property No. 2 C.**						**Property No. 17 C.**					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1898							2	777	388	125·5	132	119
1899							4	1,250	313	146·2	190	119
1900							4	3,155	788	168·2	200	119
1901	3	1,489	496	115·3	130	108	6	4,129	688	190·1	214	164
1902	4	5,685	1,421	119·2	131	108	11	6,973	634	192·1	229	164
1903												
1904												
1905												
	Property No. 3 C.						**Property No. 18 C.**					
1898							2	1,463	731	136·2	153	119
1899							3	1,222	407	141·3	153	120
1900							6	6,192	1,032	173·5	207	151
1901							7	9,303	1,329	182·1	234	151
1902	1	239	239	135	135	135	8	7,733	967	186·0	234	151
1903												
1904												
1905												
	Property No. 5 C.						**Property No. 20 C.**					
1898							1	243	243	169·0	169	169
1899	9	5,484	609	96·2	144	79	2	2,634	1,317	170·5	172	169
1900	21	11,523	548	128·7	171	84	3	6,230	2,076	179·0	196	169
1901	23	13,640	593	139·6	177	101	4	7,788	1,947	197·2	249	169
1902	18	10,296	572	161·4	230	110	5	6,836	1,367	198·0	249	169
1903												
1904												
1905												
	Property No. 13 C.						**Property No. 22 C.**					
1897							1	22	22	144·0	144	144
1898	2	692	346	179·4	205	153	2	2,129	1,064	168·8	181	156
1899	3	1,580	527	175·0	208	153	1	4,950	4,950	181·0	181	181
1900	4	3,073	768	169·2	208	152	3	1,620	540	204·3	250	181
1901	4	2,367	591	169·2	208	152	3	7,113	2,371	213·2	250	182
1902	5	2,614	523	175·4	208	152	4	5,003	1,251	203·0	250	163
1903												
1904												
1905												
	Property No. 14 C.						**Property No. 23 C.**					
1899	3	1,370	457	216·3	226	205						
1900	7	3,713	530	215·5	226	205	4	5,070	1,266	188·5	219	171
1901	12	5,329	444	214·6	226	205	8	14,133	1,766	198·2	224	175
1902	10	3,133	313	214·5	226	206	8	7,102	888	198·4	225	175
1903												
1904												
1905												
	Property No. 15 C.						**Property No. 24 C.**					
1899	6	2,372	395	222·0	227	211	1	3,674	3,647	255·0	255	255
1900	6	3,047	507	228·8	237	211	2	5,384	2,692	263·0	271	255
1901	6	2,189	364	218·8	225	211	3	4,270	1,423	242·0	271	200
1902	6	1,933	322	217·3	225	211	3	2,190	730	245·0	280	200
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Year.	**Property No. 26 C.**						**Property No. 35 C.**					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	3	477	159	137·6	147	130						
1900	4	4,901	1,225	146·5	157	130	2	6,783	3,391	190·5	214	167
1901	8	4,238	529	161·6	229	129	4	5,795	1,448	210·2	251	167
1902	8	3,153	394	165·4	229	130	5	6,979	1,396	203·0	252	167
1903												
1904												
1905												
	Property No. 29 C.						**Property No. 36 C.**					
1898	1	1,773	1,773	129·0	129	129						
1899	1	2,639	2,639	129·0	129	129						
1900	3	6,125	2,041	157·0	195	129	1	84	84	120·0	120	120
1901	3	5,592	1,864	157·0	195	129	1	1,568	1,568	158·0	158	158
1902	6	4,078	680	172·0	222	129	2	2,069	1,034	151·0	158	144
1903												
1904												
1905												
	Property No. 30 C.						**Property No. 37 C.**					
1897	1	37	37	64·0	64	64						
1898	3	1,178	392	129·6	152	100						
1899	3	1,528	1,509	129·6	152	100						
1900	4	5,383	1,345	134·2	152	100	2	1·132	566	169·5	172	167
1901	5	4,134	826	143·0	179	100	4	978	244	170·5	174	167
1902	5	2,933	587	151·8	193	129	5	432	86	171·2	174	167
1903												
1904												
1905												
	Property No. 31 C.						**Property No. 38 C.**					
1898	1	289	289	124·0	124	124						
1899	2	2,173	1,086	137·0	147	127						
1900	4	2,703	675	161·0	214	127						
1901	5	2,479	495	174·8	230	127	1	471	471	175·0	175	175
1902	6	1,618	270	183·3	230	127	2	1,690	845	199·2	224	175
1903												
1904												
1905												
	Property No. 32 C.						**Property No. 39 C.**					
1898	2	83	41	176·3	212	140						
1899	3	2,204	734	166·6	212	101						
1900	4	2,549	887	179·7	219	101						
1901	4	1,998	499	179·7	219	101	2	1,614	807	171·0	177	165
1902	6	2,847	474	196·8	261	124	2	3,683	1,841	171·0	177	165
1903												
1904												
1905												
	Property No. 33 C.						**Property No. 40 C.**					
1898	2	471	235	96·6	117	75						
1899	3	1,433	478	97·6	117	75						
1900	4	1,695	423	126·7	183	75						
1901	5	3,328	665	141·8	202	75	2	165	82	151·0	152	150
1902	6	4,443	760	159·2	219	101	5	3,653	731	202·8	216	195
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. Saboontchy—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Property No. 41 C.						**Property No. II.**					
1901	4	1,542	385	159·5	189	119						
1902	4	517	129	158·7	189	119	3	2,084	695	196	230	172
1903												
1904												
1905												
	Property No. 42 C.						**Property No. III.**					
1900	1	708	708	156·0	156	156						
1901	2	4,643	2,321	180·0	204	156	1	619	619	164·0	164	164
1902	2	3,708	1,854	188·0	220	156	2	6,761	3,380	164·0	164	164
1903												
1904												
1905												
	Property No. 191.						**Property No. 3.**					
1898							1	113	113	140·0	140	140
1899							2	133	66	137·0	140	134
1900							1	25	25	139·0	139	139
1901	1	223	223	100·0	100	100	2	24	12	157·0	174	140
1902	3	1,121	374	131·3	152	111	1	45	45	141·0	141	141
1903												
1904												
1905												
	Property No. 192.						**Property No. 4.**					
1897							1	41	41	248·0	248	248
1898							2	260	130	165·0	250	80
1899							3	663	221	152·0	145	79
1900							6	249	41	136·0	250	79
1901	1	585	585	122·0	122	122	3	90	30	119·6	145	81
1902	1	187	187	112·0	122	122	1	53	53	145·0	145	145
1903												
1904												
1905												
	Property No. 306.						**Property No. 7.**					
1899							1	26	26	149·0	149	149
1900							4	563	140	102·7	149	81
1901							4	544	136	102·7	149	81
1902	1	349	349	130	130	130	3	306	102	87·3	91	81
1903												
1904												
1905												
	Property No. I.						**Property No. 8.**					
1896							1	13	13	156·0	156	156
1897							1	79	79	145·0	145	145
1898							1	14	14	132·0	139	139
1899							1	57	57	140·0	140	140
1900							1	72	72	140·0	140	140
1901	2	1,333	666	178·0	178	178						
1902	5	4,823	965	187·0	209	161						
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Property No. 9.						**Property No. 13.**					
1896	3	1,028	342	136·0	168	90	7	5,508	786	175·0	193	152
1897	3	780	260	136·0	168	90	7	3,519	502	162·9	193	72
1898	2	633	316	82·5	100	65	7	2,149	358	162·9	193	72
1899	6	910	152	113·1	150	65	7	2,196	314	165·4	193	172
1900	7	1,269	181	106·1	136	65	6	1,701	283	182·8	193	175
1901	5	647	129	91·2	100	65	5	933	186	183·6	193	175
1902	6	594	99	98·3	134	65	5	914	183	190·6	223	175
1903												
1904												
1905												
	Property No. 10.						**Property No. 14.**					
1896	2	491	245	102·0	155	49	4	2,631	657	133·0	157	122
1897	5	720	144	76·2	155	49	9	6,518	724	146·2	179	122
1898	6	548	191	73·0	125	58	12	5,829	485	114·5	179	122
1899	5	453	91	101·2	132	58	18	8,334	463	154·6	179	120
1900	4	107	26	105·2	132	58	22	8,285	376	156·6	198	120
1901	1	3	3	132·0	132	132	27	5,484	203	161·1	199	120
1902							26	3,385	130	162·6	207	120
1903												
1904												
1905												
	Property No. 11.						**Property No. 15.**					
1896	2	340	120	98·0	148	48	7	4,416	630	151·0	194	121
1897	9	797	88	78·0	148	40	9	4,620	513	153·2	193	123
1898	16	1,452	90	90·5	153	44	8	4,321	540	153·5	199	123
1899	18	1,618	90	80·4	153	48	10	3,743	374	148·4	193	123
1900	14	739	52	71·3	122	48	11	3,104	282	148·6	179	123
1901	12	674	56	74·8	119	48	9	1,553	172	155·5	191	130
1902	6	407	68	67·5	90	57	1	722	722	191·0	191	191
1903												
1904												
1905												
	Property No. 12.						**Property No. 16.**					
1896	3	439	146	137·0	203	64	3	3,307	1,102	171·0	187	156
1897	4	583	145	115·2	203	49	5	4,991	989	170·8	187	131
1898	7	1,104	157	100·1	203	63	9	7,454	828	157·8	187	131
1899	10	2,003	200	122·4	203	59	11	8,308	755	158·2	188	131
1900	10	2,025	202	129·3	203	85	13	6,282	483	163·2	188	131
1901	9	1,522	169	128·7	203	85	15	3,944	262	167·0	189	131
1902	9	1,401	156	127·8	196	85	13	4,227	325	171·5	192	132
1903												
1904												
1905												
	Property No. 12 C.						**Property No. 17.**					
1896							9	4,257	473	149·0	183	120
1897							9	4,350	483	156·6	183	138
1898							12	3,317	276	143·7	193	113
1899							11	4,027	366	151·3	193	124
1900							15	4,399	293	162·8	196	124
1901	1	145	145	121·0	121	121	18	5,320	295	172·9	215	124
1902	4	680	170	153·2	223	96	16	5,477	342	171·1	215	124
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Year.	Property No. 18.						Property No. 24.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	2	354	177	109·0	135	83	1	151	151	67·0	67	67
1897	3	477	158	120·8	156	71	3	363	121	103·0	122	75
1898	5	1,040	208	125·4	156	71	4	887	221	131·1	167	116
1899	4	1,032	258	120·5	156	71	5	1,229	244	131·4	168	116
1900	5	1,317	263	136·2	170	71	5	988	197	131·4	168	116
1901	4	1,033	258	145·7	170	120	5	454	90	131·4	168	116
1902	5	1,911	382	152·0	177	120	3	397	132	136·3	168	117
1903												
1904												
1905												
	Property No. 19.						Property No. 25.					
1896	5	3,746	749	156·0	193	140	2	501	250	161·0	167	155
1897	6	3,052	508	146·4	155	140	3	801	267	148·8	174	114
1898	8	3,482	435	144·7	152	140	3	548	183	154·4	174	131
1899	9	3,146	349	143·4	153	135	3	638	213	154 3	174	131
1900	10	3,029	302	143·1	153	135	3	384	128	154·3	174	131
1901	9	1,677	186	142·1	153	135	4	679	169	172·7	189	158
1902	5	777	155	141·0	153	135	4	768	192	172·7	189	158
1903												
1904												
1905												
	Property No. 20.						Property No. 26.					
1896	5	1,795	359	127·7	138	120	4	1,878	469	140·0	144	128
1897	6	2,391	398	131·5	140	123	4	1,634	408	140·7	157	129
1898	6	2,103	350	134·9	154	123	5	1,233	246	138·8	157	129
1899	8	2,022	253	123·3	154	74	8	1,380	172	144·5	167	111
1900	14	4,550	325	135·0	154	112	12	1,615	134	129·5	167	92
1901	22	7,483	340	138·8	167	116	13	1,638	126	133·6	167	92
1902	24	5,885	245	141·6	171	116	9	1,105	123	151·1	229	111
1903												
1904												
1905												
	Property No. 21.						Property No. 27.					
1896	7	1,763	251	118·7	127	86	2	449	224	156·0	156	156
1897	4	1,023	255	123·6	130	115	2	652	326	141·0	155	127
1898	4	516	129	123·5	130	115	2	561	280	154·5	164	155
1899	4	249	62	128·6	136	121	3	629	210	140·2	164	103
1900	3	256	85	128·0	136	121	5	797	159	141·0	178	98
1901	4	373	93	147·7	195	121	4	571	142	148·2	178	98
1902	2	433	216	176·0	195	157	5	515	103	152·8	183	115
1903												
1904												
1905												
	Property No. 22.						Property No. 28.					
1896	3	165	52	89·0	106	66	7	2,532	366	126·0	160	91
1897	6	956	159	75·9	95	58	7	2,760	394	131·6	160	91
1898	6	987	164	93·3	105	67	6	2,178	363	136·0	152	114
1899	3	1,574	197	109·6	156	67	8	2,212	276	136·6	160	114
1900	15	1,781	118	118·7	208	67	9	1,975	219	137·8	160	114
1901	17	2,269	133	120·3	208	95	9	1,593	177	139·4	160	114
1902	17	2,003	118	122·6	208	95	8	1,284	160	137·7	160	114
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

	Property No. 29.						**Property No. 36.**					
Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	3	2,512	814	155·0	158	152	4	1,235	308	129·0	165	117
1897	4	1,874	468	131·0	151	92	5	1,787	357	128·4	174	112
1898	5	1,468	293	141·9	176	92	4	859	214	156·1	159	117
1899	3	383	128	126·6	151	92	4	2,259	564	130·2	159	117
1900	5	303	60	118·4	156	92	6	2,583	430	137·3	181	117
1901	4	214	53	141·2	164	92	6	1,652	275	153·0	186	117
1902	2	3	1	122·5	153	92	6	1,478	246	142·2	181	117
1903												
1904												
1905												
	Property No. 31.						**Property No. 37.**					
1896	4	877	219	120·0	171	85	2	1,039	509	152·0	156	148
1897	4	758	189	135·0	166	123	3	645	215	148·3	161	136
1898	3	573	191	148·0	166	123	4	1,011	252	147·5	161	136
1899	6	1,639	273	133·5	166	105	4	1,091	273	151·5	161	138
1900	8	1,900	237	123·0	144	99	4	407	101	156·2	161	148
1901	11	2,110	191	132·9	166	99	3	140	46	155·3	161	148
1902	11	1,556	141	123·9	157	98						
1903												
1904												
1905												
	Property No. 32.						**Property No. 38.**					
1896	5	1,517	305	154·0	184	125	6	1,571	261	147·6	196	118
1897	7	1,683	240	161·9	210	125	4	2,144	536	134·0	141	118
1898	6	1,103	183	121·4	175	125	6	1,102	183	110·1	156	118
1899	7	1,176	168	151·0	175	125	4	1,675	419	130·2	144	118
1900	7	1,128	161	146·2	170	125	5	639	127	134·2	144	119
1901	5	689	137	147·6	170	125	4	799	199	133·0	144	119
1902	5	772	154	149·2	170	125	4	736	184	133·0	144	119
1903												
1904												
1905												
	Property No. 33.						**Property No. 39.**					
1896	1	60	60	185·0	185	185						
1897							1	275	275	87·0	87	87
1898	1	515	515	136·0	136	136	1	86	86	87·0	87	87
1899	1	605	605	136·0	136	136	1	3	3	135·0	135	135
1900	3	547	182	162·3	214	136						
1901	4	486	121	157·5	214	135						
1902	4	609	152	157·5	214	135						
1903												
1904												
1905												
	Property No. 35.						**Property No. 40.**					
1896							3	878	292	106·0	119	89
1897							5	1,898	379	106·0	123	88
1898							8	2,585	339	116·1	140	101
1899	1	202	202	157·0	157	157	10	2,384	238	131·1	167	88
1900	1	222	222	157·0	157	157	12	1,763	146	140·8	168	101
1901	1	185	185	157·0	157	157	14	2,168	154	135·9	170	88
1902	1	118	118	157·0	157	157	13	1,386	107	136·5	170	88
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

	Property No. 41.						**Property No. 46.**					
Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	3	1,132	377	124·0	139	114	7	2,566	366	145·0	204	107
1897	4	1,406	351	127·4	139	114	7	2,455	350	144·9	205	107
1898	3	1,400	466	123·3	136	114	7	2,592	370	149·9	205	110
1899	1	12	12	120·0	120	120	6	1,371	228	154·5	205	109
1900							5	1,066	213	171·2	205	128
1901							6	834	139	168·5	205	128
1902	2	502	251	155·6	189	121	5	1,064	213	108·0	205	148
1903												
1904												
1905												
	Property No. 42.						**Property No. 47.**					
1896	5	1,590	318	159·0	175	140	6	1,967	327	123·0	155	71
1897	5	1,656	331	162·4	210	140	6	3,617	602	125·1	155	92
1898	6	1,535	255	153·2	176	140	8	4,195	524	127·9	172	103
1899	6	1,941	323	151·1	176	139	9	3,991	443	125·6	171	103
1900	10	1,978	197	142·1	176	100	9	1,130	125	119·6	155	103
1901	15	2,485	165	145·9	181	100	8	837	104	124·1	166	103
1902	11	1,410	128	144·3	176	100	8	647	.81	130·0	166	109
1903												
1904												
1905												
	Property No. 43.						**Property No. 48.**					
1896	2	498	249	144·0	186	102	6	3,878	646	140·0	201	103
1897	3	643	214	106·7	114	99	5	5,089	1,017	161·4	212	103
1898	4	580	145	119·4	131	106	9	1,412	156	116·5	201	112
1899	2	384	192	124·0	142	106	6	848	141	137·0	201	106
1900	2	231	115	124·0	142	106	5	532	106	143·8	201	106
1901	2	206	103	181·5	131	106	6	796	132	140·5	201	106
1902	2	450	225	118·5	131	106	4	611	153	136·5	198	106
1903												
1904												
1905												
	Property No. 44.						**Property No. 49.**					
1896	2	599	299	173·0	184	162	1	344	344	162·0	162	162
1897	2	426	213	177·5	183	172	1	688	688	171·0	171	171
1898	2	291	145	177·5	183	172	2	955	477	192·4	202	183
1899	2	234	117	177·5	183	172	2	640	320	193·0	202	184
1900	2	195	97	177·5	183	172						
1901	2	117	58	177·5	183	172	1	192	192	179·0	179	179
1902							1	21	21	179·0	179	179
1903												
1904												
1905												
	Property No. 45.						**Property No. 50.**					
1896	3	386	128	148·0	182	88	8	5,135	641	137·0	183	62
1897	3	468	156	151·3	180	124	8	3,098	387	129·5	172	84
1898	3	423	141	151·3	180	124	13	4,869	374	146·4	184	90
1899	2	470	235	164·5	180	149	17	4,266	251	146·3	189	90
1900	2	449	224	164·5	180	149	29	6,282	216	153·2	219	90
1901	2	303	151	164·5	180	149	40	10,533	264	157·9	219	98
1902	2	252	126	164·5	180	149	35	8,556	244	165·6	219	86
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Property No. 51.						**Property No. 59.**					
1896	1	4	4	157·0	157	157						
1897	1	1	1	157·0	157	157						
1898	1	7	7	157·0	157	157	2	552	276	143·5	147	140
1899							2	773	386	121·0	147	95
1900							2	975	487	150·0	153	147
1901							5	997	199	166·0	207	138
1902							5	2,446	489	183·0	229	138
1903												
1904												
1905												
	Property No. 52.						**Property No. 60.**					
1896	2	707	353	160·5	169	152	1	167	167	120·0	120	120
1897	2	499	249	160·5	169	152	1	468	468	118·0	118	118
1898	2	431	170	160·5	169	152	1	425	425	117·0	117	117
1899	2	90	45	160·5	169	152	1	147	147	117·0	117	117
1900							1	6	6	117·0	117	117
1901							1	120	120	222·0	222	222
1902	1	2	2	172·0	172	172	1	26	6	222·0	222	222
1903												
1904												
1905												
	Property No. 54.						**Property No. 61.**					
1896	1	167	167	100·0	109	109	1	1,088	1,088	165·0	165	165
1897	3	1,659	553	111·5	114	108	1	10	10	147·0	147	147
1898	5	1,449	289	117·8	133	108	2	71	35	177·5	192	163
1899	5	939	188	117·8	133	108	1	2,747	2,747	192·0	192	192
1900	5	790	158	122·2	155	108	2	2,416	2,208	177·5	192	163
1901	4	449	112	137·5	214	108	3	3,697	1,232	175·3	192	161
1902	3	425	142	112·0	114	108	3	1,439	479	165·7	173	161
1903												
1904												
1905												
	Property No. 56.						**Property No. 62.**					
1896	8	2,239	279	107·0	211	31						
1897	8	1,598	199	106·1	204	31						
1898	12	2,029	169	131·2	204	82						
1899	13	2,096	161	129·9	241	30	1	109	109	163·0	163	163
1900	16	3,078	192	120·3	241	31	2	474	237	166·0	169	163
1901	17	3,549	208	132·8	241	31	1	407	407	193·0	193	193
1902	11	2,883	262	170·5	241	100	3	1,301	434	199·7	211	193
1903												
1904												
1905												
	Property No. 57.						**Property No. 64.**					
1898							1	0·3	0·3	211·0	211	211
1899	1	112	112	158·0	158	158	2	184	92	205·0	211	199
1900	1	350	350	130·0	130	130	2	659	329	207·0	211	203
1901	3	793	264	157·0	213	128	1	248	248	211·0	211	211
1902	4	1,347	337	172·2	217	129	2	34	17	209·0	214	204
1903												
1904												
1905												
	Property No. 58.						**Property No. 67.**					
1896							3	1,346	448	156·0	159	151
1897							1	748	748	151·0	151	151
1898	1	499	499	144·0	144	144						
1899	3	536	178	126·0	144	115	1	54	54	162·0	162	162
1900	4	985	246	131·0	144	119	1	172	172	155·0	155	155
1901	8	2,558	319	153·0	198	123	2	812	406	164·5	174	155
1902	8	2,939	367	157·4	216	123	5	1,356	271	167·8	175	151
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Property No. 68.						**Property No. 75.**					
1898	5	1,752	350	128·2	184	102						
1899	7	2,661	380	120·5	126	115						
1900	5	3,152	630	127·6	139	155	1	143	143	178·0	178	178
1901	10	3,860	386	151·8	220	122	3	919	306	192·3	248	140
1902	13	3,549	273	167·2	233	122	2	550	275	194·0	248	140
1903												
1904												
1905												
	Property No. 69.						**Property No. 12.**					
1896	1	44	44	160·0	160	160	6	3,267	544	179·0	214	142
1897	2	811	405	153·5	167	140	7	5,803	829	176·9	221	142
1898	2	1,550	775	159·5	167	151	2	2,553	1,276	180·0	199	161
1899	3	3,813	1,271	152·0	153	151	4	593	148	176·5	194	161
1900	8	4,880	610	155·7	173	143	5	1,078	215	182·6	203	165
1901	13	4,961	381	157·7	186	141	7	3,432	490	170·4	203	144
1902	10	3,691	369	162·9	205	143	6	3,323	554	161·7	176	144
1903												
1904												
1905												
	Property No. 70.						**Property No. 137.**					
1899	1	89	89	159·0	159	159						
1900	1	107	107	160·0	160	160						
1901	3	3,186	1,062	172·3	185	160	2	2,788	1,394	213·5	217	210
1902	5	4,259	852	182·2	201	160	2	2,008	1,004	213·5	217	210
1903												
1904												
1905												
	Property No. 71.						**Property No. 146.**					
1896	2	2,756	1,378	145·0	156	135						
1897	5	3,754	750	127·9	156	112						
1898	7	2,611	373	129·5	156	112						
1899	8	2,551	319	132·6	157	112						
1900	8	1,955	244	135·2	178	112	1	17	17	276·0	276	276
1901	10	2,016	201	161·2	206	122						
1902	10	2,033	203	165·7	206	129	2	315	157	239·0	263	215
1903												
1904												
1905												
	Property No. 72.						**Property No. 147.**					
1896	9	4,425	491	145·0	176	105						
1897	12	4,454	370	145·2	175	109						
1898	13	4,182	321	147·2	175	109						
1899	13	2,987	230	144·3	175	106						
1900	13	5,854	450	158·7	183	112						
1901	13	5,428	417	164·0	224	112	1	122	122	215·0	215	215
1902	11	2,918	265	179·1	224	137	1	520	520	251·0	251	251
1903												
1904												
1905												
	Property No. 73.						**Property No. 148.**					
1896	5	1,479	295	156·0	196	134						
1897	3	1,572	524	153·0	168	140						
1898	3	1,074	358	153·0	168	140						
1899	2	164	82	159·5	168	151						
1900	1	207	207	168·0	168	168						
1901	2	495	247	162·0	168	156	1	1,030	1,030	284·0	284	284
1902	2	470	235	166·0	176	156	1	10	10	284·0	284	284
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Property No. 151.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1900	1	96	96	197·0	197	197
1901	1	532	532	298·0	298	298
1902	1	24	24	225·0	225	225
1903						
1904						
1905						

Property No. 161.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1900						
1901	2	440	220	161·0	161	161
1902	2	298	149	169·0	177	161
1903						
1904						
1905						

Property No. 152.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896						
1897	1	23	23	188·0	188	188
1898	2	615	307	184·5	188	188
1899	1	87	87	188·0	188	188
1900	1	210	210	188·0	188	188
1901	1	1,488	1,488	188·0	188	188
1902	1	602	602	188·0	188	188
1903						
1904						
1905						

Property No. 162.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	1	1,689	1,689	167·0	167	167
1897	2	44	22	182·0	201	163
1898	3	2,206	735	178·3	212	160
1899	3	2,290	763	178·3	212	160
1900	4	894	223	174·2	212	160
1901	1	211	211	165·0	165	165
1902						
1903						
1904						
1905						

Property No. 154.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899	2	192	96	200·0	208	192
1900	2	80	40	200·0	208	192
1901	2	62	31	218·5	229	220
1902						
1903						
1904						
1905						

Property No. 163.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1899						
1900						
1901	1	152	152	187·0	187	187
1902	1	383	383	187·0	187	187
1903						
1904						
1905						

Property No. 158.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896						
1897						
1898	2	722	161	161·5	187	136
1899	2	1,705	853	157·5	187	128
1900	1	11	11	187·0	187	187
1901	1	9	9	128·0	128	128
1902	5	1,098	219	212·2	244	179
1903						
1904						
1905						

Property No. 164.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	3	1,233	411	153·0	167	139
1897	3	1,976	658	156·7	167	149
1898	4	5,050	1,262	173·0	222	149
1899	2	2,489	1,244	185·5	222	149
1900	2	1,418	709	185·5	222	149
1901	1	58	58	234·0	234	234
1902	3	609	203	211·7	244	149
1903						
1904						
1905						

Property No. 159.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896						
1897						
1898						
1899	1	39	39	138·0	138	138
1900	2	1,647	823	150·0	162	138
1901	3	523	174	155·6	189	116
1902	4	1,419	355	172·5	189	162
1903						
1904						
1905						

Property No. 165.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	1	360	360	141·0	141	141
1897	2	2,101	1,050	186·0	204	168
1898	2	4,313	2,156	192·7	217	168
1899	3	1,489	496	180·0	217	155
1900	4	2,907	726	183·0	217	155
1901	5	3,329	665	193·4	235	155
1902	6	1,222	204	217·2	265	155
1903						
1904						
1905						

Property No. 160.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	1	684	684	171·0	171	171
1897	1	517	517	136·0	136	136
1898						
1899	1	302	302	160·0	160	160
1900	1	179	179	160·0	160	160
1901	1	215	215	160·0	160	160
1902						
1903						
1904						
1905						

Property No. 166.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	3	666	222	171·0	230	141
1897	4	302	75	147·5	230	90
1898	5	2,306	461	170·6	230	129
1899	6	1,602	267	156·3	175	140
1900	7	759	108	165·7	179	151
1901	6	3,003	500	187·3	241	156
1902	10	1,484	148	206·8	265	156
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY. Saboontchy—(*contd.*)

Year.	Property No. 167.						Property No. 172.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	5	3,440	688	148·1	208	100	3	1,620	540	164·0	178	148
1897	6	2,834	472	160·7	220	127	4	1,064	226	170·1	178	162
1898	6	11,272	1,878	186·8	223	127	6	3,368	561	152·6	227	162
1899	4	7,135	1,784	197·2	223	161	5	31,150	6,230	194·2	227	162
1900	8	10,572	1,321	207·0	234	161	3	5,688	1,896	185·3	204	162
1901	10	14,732	1,473	201·9	242	161	4	2,388	597	196·7	216	162
1902	8	5,229	654	206·2	249	173	5	1,159	232	221·8	251	194
1903												
1904												
1905												

Year.	Property No. 168.						Property No. 173.					
1896	1	136	136	148·0	148	148	4	6,122	1,530	150·0	190	119
1897	1	1	1	156·0	156	156	5	11,763	2,352	147·6	166	117
1898	1	67	67	160·0	160	160	10	9,193	919	147·9	170	109
1899							10	2,225	222	169·8	205	117
1900	1	724	724	183·0	183	183	13	4,455	342	168·9	205	117
1901	2	586	293	203·0	223	183	14	3,936	281	181·7	230	159
1902	5	2,267	453	237·6	263	183	16	8,137	509	185·9	240	159
1903												
1904												
1905												

Year.	Property No. 169.						Property No. 174.					
1896	5	3,149	629	141·0	202	65	6	5,647	941	134·0	180	100
1897	3	5,177	1,762	166·7	202	140	8	7,866	983	159·1	224	75
1898	9	8,093	899	224·3	220	128	8	7,076	884	154·1	224	35
1899	11	11,941	1,085	177·5	220	62	9	6,562	729	160·7	224	35
1900	15	1,387	759	175·0	229	62	9	5,625	625	164·8	261	35
1901	15	3,600	906	190·0	239	127	7	3,841	548	143·7	217	35
1902	14	7,807	558	203·4	249	166	7	2,952	422	180·3	217	98
1903												
1904												
1905												

Year.	Property No. 170.						Property No. 175.					
1896							22	16,511	750	160·0	223	48
1897							19	12,736	670	162·0	220	48
1898							21	10,515	500	176·2	224	48
1899	1	382	382	209·0	209	209	19	8,775	462	176·9	224	105
1900							20	7,192	359	177·9	224	105
1901	1	536	536	203·0	203	203	22	6,001	272	180·0	224	105
1902	1	1,505	1,505	203·0	203	203	20	4,206	210	184·8	230	105
1903												
1904												
1905												

Year.	Property No. 171.						Property No. 176.					
1896	2	3,054	1,527	175·0	211	139	1	211	211	203·0	203	203
1897	2	377	188	175·5	176	175						
1898	1	38	38	199·0	199	199						
1899												
1900												
1901	2	2,642	1,321	222·5	269	176						
1902	3	2,889	963	269·3	272	267						
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. SABOONTCHY—(*contd.*)

Property No. 177.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	1	68	68	149·0	149	149
1897						
1898	1	0·6	0·6	139·0	139	139
1899	1	237	237	135·0	135	135
1900	1	457	457	160·0	160	160
1901	1	418	418	160·0	160	160
1902	2	360	180	166·5	173	160
1903						
1904						
1905						

Property No. 178.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	6	4,593	765	131·0	166	90
1897	6	4,365	727	154·8	191	137
1898	7	3,834	547	159·2	191	137
1899	8	3,836	479	163·7	196	137
1900	9	3,913	434	170·8	201	137
1901	12	5,532	461	181·4	219	137
1902	10	3,931	393	174·9	201	137
1903						
1904						
1905						

Property No. 179.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	6	2,416	402	143·0	170	106
1897	6	2,673	445	150·4	190	106
1898	6	1,744	290	148·1	207	106
1899	6	1,613	269	152·8	207	114
1900	8	2,061	257	139·6	168	114
1901	9	1,886	209	139·8	168	114
1902	10	1,956	196	149·1	210	114
1903						
1904						
1905						

Property No. 180.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	2	564	282	147·0	178	116
1897	5	1,899	379	151·9	196	116
1898	4	1,493	373	145·5	178	134
1899	5	1,040	208	154·6	192	134
1900	5	997	199	155·0	194	134
1901	4	616	154	145·2	178	134
1902	4	535	134	147·7	187	134
1903						
1904						
1905						

Property No. 181.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	3	274	91	143·0	175	112
1897	3	409	136	159·0	175	142
1898	2	460	230	158·5	175	142
1899	2	347	174	161·0	175	147
1900	3	366	122	149·6	175	123
1901	4	345	86	156·2	175	126
1902	3	563	188	161·0	184	124
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE GROUP.

SABOONTCHY—(*contd.*)

Group No. V.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	24	7,841	326	108·7	176	22
1897	26	8,300	319	104·4	153	22
1898	32	6,641	207	103·6	153	22
1899	31	4,569	147	112·9	165	28
1900	32	4,333	135	117·5	165	50
1901	32	3,551	110	119·6	168	152
1902	21	2,141	102	128·3	176	74
1903						
1904						
1905						

Group No. XVI.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	23	5,705	248	116·0	170	70
1897	26	4,087	157	121·5	170	73
1898	28	3,910	139	125·8	170	85
1899	36	4,996	139	125·1	185	69
1900	36	6,026	167	131·3	217	79
1901	37	4,757	128	131·4	217	79
1902	27	2,927	108	132·4	185	93
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

ROMANY.

Year.	Property No. 33.						Property No. 42.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896							4	2,209	552	191·0	241	170
1897							3	1,343	447	186·7	241	148
1898							3	1,715	571	186·7	241	148
1899							5	1,439	288	202·2	241	148
1900							7	1,430	204	195·4	241	120
1901	1	5,167	5,167	180·0	180	180	7	2,921	417	205·4	252	148
1902	3	4,506	1,502	179·7	180	179	6	915	153	216·0	268	148
1903												
1904												
1905												

Year.	Property No. 35.						Property No. 43.					
1896							2	2,194	1,097	178·0	192	165
1897							2	2,739	1,369	178·0	192	165
1898	1	852	852	216·0	216	216	3	2,065	688	221·3	238	192
1899	1	619	619	216·0	216	216	4	1,480	370	226·2	241	192
1900	1	461	461	216·0	216	216	4	1,003	250	226·2	241	192
1901	2	468	234	194·5	216	173	4	507	126	226·2	241	192
1902	2	1,088	544	205·0	237	173	4	398	99	226·2	241	192
1903												
1904												
1905												

Year.	Property No. 36.						Property No. 44.					
1896							2	742	371	183·0	209	177
1897							2	643	321	191·1	204	178
1898							4	611	152	193·7	231	162
1899							3	396	132	220·6	231	204
1900							3	462	154	220·6	231	204
1901	2	115	57	206·0	208	204	3	350	116	197·6	227	162
1902	2	910	455	252·0	300	204	2	146	73	217·5	231	204
1903												
1904												
1905												

Year.	Property No. 38.						Property No. 45.					
1896	21	24,149	1,007	150·0	222	71	3	2,707	902	181·0	217	152
1897	24	21,542	897	164·8	232	87	3	1,100	366	181·0	217	152
1898	24	17,403	725	184·2	232	115	3	1,288	429	181·0	117	152
1899	34	18,845	554	182·9	254	90	4	1,210	302	197·0	236	152
1900	43	20,950	487	186·0	254	115	4	843	210	197·7	236	152
1901	47	23,910	508	190·3	254	115	5	874	174	196·0	236	152
1902	44	19,354	440	196·8	254	115	5	759	152	196·0	236	152
1903												
1904												
1905												

Year.	Property No. 40.						Property No. 46.					
1896	1	48	48	167·0	167	167	4	3,833	958	159·7	222	68
1897	2	739	369	206·4	215	197	7	4,274	610	159·7	222	68
1898	3	1,447	482	179·2	220	120	4	3,611	515	171·5	222	68
1899	3	1,052	351	179·0	220	120	11	4,305	391	174·8	232	68
1900	2	845	422	208·5	220	197	19	6,169	324	159·0	256	68
1901	4	1,642	410	202·5	233	170	20	9,166	458	193·2	256	92
1902	5	1,364	273	202·8	233	170	19	6,970	367	172·9	236	92
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. ROMANY—(*contd.*)

	Property No. 47.						Property No. 96.					
Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	5	2,376	495	143·0	221	110	2	1,873	936	167·5	181	154
1897	6	3,988	664	143·5	221	110	1	119	119	189·0	189	189
1898	6	2,741	456	143·7	221	110	3	1,833	611	196·0	218	181
1899	7	4,009	587	149·1	226	46	3	867	289	196·0	218	181
1900	9	3,473	385	177·8	240	110	3	276	92	196·0	218	181
1901	8	2,284	285	178·7	244	110	3	127	42	196·0	218	181
1902	9	2,511	279	191·7	248	110						
1903												
1904												
1905												
	Property No. 48.						**Property No. 97.**					
1896	7	10,487	1,498	153·3	201	109	1	2,390	2,390	213·0	213	213
1897	8	9,201	1,150	164·0	221	109	2	835	417	214·7	217	212
1898	8	6,590	823	194·0	221	109	3	1,091	363	206·0	220	181
1899	10	11,258	1,126	178·9	237	109	3	2,587	862	203·0	220	181
1900	11	9,859	896	198·8	249	141	5	277	55	193·4	220	156
1901	13	9,392	722	204·2	249	162	5	193	38	208·0	226	181
1902	12	9,335	778	201·9	246	162	4	163	41	213·7	233	181
1903												
1904												
1905												
	Property No. 58.						**Property No. 102.**					
1896	3	4,844	1,614	192·6	249	157	7	3,739	534	159·4	209	110
1897	5	5,605	1,121	179·0	249	157	10	10,815	1,081	162·3	209	110
1898	4	8,475	2,118	187·5	215	157	11	7,207	655	171·7	221	110
1899	4	5,456	1,364	195·5	215	157	12	4,929	411	189·7	236	136
1900	7	4,867	695	217·1	258	157	10	3,100	310	196·8	237	136
1901	13	10,626	817	209·6	258	141	8	4,297	537	206·7	237	143
1902	16	8,706	544	213·9	258	141	11	10,496	954	215·0	243	143
1903												
1904												
1905												
	Property No. 76.						**Property No. 103.**					
1896	1	193	193	170·0	170	170	9	8,451	939	138·3	202	63
1897	1	10	10	171·0	171	171	9	5,813	645	139·8	202	63
1898	2	4,155	2,077	180·5	185	176	10	23,335	2,335	150·7	190	63
1899	2	8,898	4,449	180·5	185	176	10	7,808	781	164·1	196	105
1900	2	7,809	3,901	217·5	250	185	12	20,821	1,735	169·8	237	105
1901	4	10,918	2,729	208·0	250	177	13	21,192	1,630	197·5	260	105
1902	7	14,089	2,013	205·4	252	172	14	19,294	1,378	213·0	263	160
1903												
1904												
1905												
	Property No. 95.						**Property No. 107.**					
1896	3	2,244	748	152·0	178	139	3	1,072	337	165·0	181	148
1897	6	2,106	351	187·5	251	140	4	6,676	1,669	197·7	221	159
1898	5	2,245	449	173·4	215	140	4	10,689	2,672	206·6	236	159
1899	6	2,728	455	171·3	215	140	2	4,645	2,322	197·5	236	159
1900	7	2,554	364	178·5	215	146	11	9,673	879	184·8	243	152
1901	7	273	39	207·7	232	146	15	8,915	594	191·6	242	146
1902	7	302	43	200·1	232	146	17	22,517	1,325	206·3	257	146
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. ROMANY—(*contd.*)

Year.	Property No. 140.						Property No. 28.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896							1	1,538	1,538	207·0	207	207
1897	1	16	16	248·0	248	248	1	13,061	13,061	207·0	207	207
1898	1	27	27	238·0	238	238	2	914	457	208·0	209	207
1899	1	323	323	238·0	238	238	4	1,456	364	215·2	239	205
1900	1	805	805	238·0	238	238	2	1,444	722	205·5	206	205
1901							1	369	369	205·0	205	205
1902	1	15	15	329·0	329	329						
1903												
1904												
1905												

Year.	Property No. 6 R.						Property No. 30.					
1900	4	897	224	183·7	247	130						
1901	4	1,131	282	196·0	247	160	2	555	277	197·6	207	188
1902	3	1,275	425	275·3	294	247	1	207	206	191·0	191	191
1903												
1904												
1905												

Year.	Property No. 26 R.						Property No. 31.					
1896	1	1,827	1,827	224·0	224	224	2	127	63	177·0	179	175
1897	1	34	34	222·0	224	224	1	55	55	177·0	177	177
1898	1	71	71	240·0	240	240	2	220	110	187·0	187	187
1899	2	3,259	1,629	199·0	240	158	2	8,338	4,169	203·0	206	200
1900	3	1,783	594	239·3	244	234	1	10,181	10,181	206·0	206	206
1901	4	1,747	436	250·0	261	240	2	2,429	1,214	206·0	206	206
1902	4	1,601	400	250·0	261	240	3	3,130	1,043	209·3	216	206
1903												
1904												
1905												

Year.	Property No. 27 R.						Property No. 32.					
1896							1	176	176	186·5	186	186
1897							3	3,927	1,309	197·3	203	187
1898							2	630	315	211·8	236	187
1899	1	35	35	111·0	111	111	3	1,204	401	213·3	236	187
1900	5	939	187	270·8	270	132	6	1,971	394	224·6	259	170
1901	8	2,779	347	210·8	234	161	4	1,624	406	218·5	259	170
1902	10	3,810	381	235·3	295	161	5	2,718	543	204·8	259	170
1903												
1904												
1905												

Year.	Property No. 23.						Property No. 33.					
1897							1	1,507	1,507	184·0	184	184
1898							1	604	604	184·0	184	184
1899							1	593	593	184·0	184	184
1900							3	398	132	207·0	244	184
1901							3	43	14	226·6	252	144
1902	1	180	180	206·0	206	206	1	1,387	1,387	257·0	257	257
1903												
1904												
1905												

Year.	Property No. 25.					
1901	1	140	140	189·0	189	189
1902	1	535	535	195·0	195	195
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

BIBI-EIBAT.

	Property No. 3 B-E.						Property No. 46 B-E.					
Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1900							4	949	237	131·0	142	108
1901							5	1,687	337	188·5	218	139
1902	1	898	898	284	284	284	4	123	31	188·5	218	139
1903												
1904												
1905												
	Property No. 6 B-E.						Property-No. 47 B-E.					
1900	1	172	172	151·0	151	151						
1901	2	16,174	8,087	205·0	259	151	3	1,867	622	138·3	143	136
1902	2	2,156	1,078	205·0	259	151	1	1,197	1,197	136·0	136	136
1903												
1904												
1905												
	Property No. 11 B-E.						Property No. 48 B-E.					
1900	2	580	290	115·0	121	109	2	712	356	120·0	131	109
1901	4	1,775	443	136·2	199	73	3	1,926	385	134·0	149	109
1902	4	2,762	691	136·2	199	73	5	116	23	136·4	151	109
1903												
1904												
1905												
	Property No. 14 B-E.						Property No. 49 B-E.					
1900	2	1,067	532	151·0	170	132	3	1,872	624	147·0	170	135
1901	1	209	209	170·0	170	170	4	1,798	449	166·2	224	135
1902	3	1,048	349	272·7	300	224	5	1,845	369	193·2	269	136
1903												
1904												
1905												
	Property No. 15 B-E.						Property No. 50 B-E.					
1900							5	2,550	510	105·2	128	75
1901	3	1,889	629	173·0	217	134	10	5,332	533	136·5	180	91
1902	5	7,956	1,591	244·2	272	223	1	54	54	178·0	178	178
1903												
1904												
1905												
	Property No. 16 B-E.						Property No. 51 B-E.					
1900	2	477	238	155·0	160	150	2	250	125	141·5	155	128
1901	2	71	35	199·5	223	176	4	2,006	501	142·0	163	122
1902	1	97	97	176·0	176	176	4	1,103	276	151·5	193	122
1903												
1904												
1905												
	Property No. 45 B-E.						Property No. 52 B-E.					
1900	2	411	205	122·5	126	119	3	473	157	135·0	148	119
1901	2	203	101	122·5	126	119	4	518	129	186·5	238	139
1902	1	26	26	119·0	119	119	4	595	149	207·2	264	168
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. BIBI-EIBAT—(*contd.*)

	Property No. 54 B-E.						Property No. 28.					
Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896							4	1,607	401	173·0	231	100
1897							5	6,581	1,316	207·0	231	175
1898							6	2,189	364	214·3	250	175
1899							6	1,883	314	214·3	250	175
1900	4	2,601	650	111·5	116	107	7	1,583	226	204·7	250	147
1901	4	4,143	1,035	115·7	129	107	4	721	180	217·0	250	175
1902	2	410	205	109·0	111	107	3	326	109	222·0	250	175
1903												
1904												
1905												
	Property No. 55 B-E.						Property No. 29.					
1896							2	1,396	698	181·5	188	175
1897							4	3,678	919	215·6	242	175
1898							8	14,623	1,827	211·9	241	175
1899							8	6,226	788	224·7	251	175
1900	6	3,853	642	125·2	145	108	8	8,650	1,081	226·1	262	175
1901	6	2,671	445	149·8	187	122	7	16,625	2,375	235·5	262	197
1902	9	12,644	1,405	179·0	243	122	6	18,873	3,146	243·5	262	197
1903												
1904												
1905												
	Property No. 56 B-E.						Property No. 36.					
1896							3	2,286	762	170·0	186	150
1897							4	2,880	720	181·2	216	150
1898							3	1,883	627	208·0	222	186
1899							5	6,574	1,315	211·8	262	173
1900							4	7,298	1,824	218·2	262	173
1901	5	2,217	443	167·4	205	121	5	9,373	1,874	211·8	262	173
1902	5	2,925	585	182·2	250	121	2	1,871	936	239·0	262	216
1903												
1904												
1905												
	Property No. 57 B-E.						Property No. 37.					
1896							2	577	288	197·0	203	192
1897							2	770	385	197·0	203	192
1898							3	1,453	484	218·6	261	192
1899							4	10,986	2,746	231·5	270	192
1900	1	504	504	108·0	108	108	6	13,537	2,256	225·6	270	192
1901	4	3,449	862	109·5	113	107	7	5,716	816	230·4	270	192
1902	3	153	51	110·3	113	108	8	6,509	814	236·2	275	192
1903												
1904												
1905												
	Property No. 27.						Property No. 38.					
1896	5	870	174	164·0	197	143	1	2	2	192·0	192	192
1897	5	1,865	373	176·8	208	145	1	258	258	252·0	252	252
1898	7	10,465	1,495	197·1	224	150	1	699	699	252·0	252	252
1899	6	8,298	1,383	216·5	258	178	2	893	447	268·5	285	252
1900	6	9,876	1,646	215·5	258	178	2	1,215	607	268·5	285	252
1901	6	5,238	873	215·5	258	178	2	582	291	268·5	285	252
1902	6	4,724	787	233·0	287	178	2	621	310	268·5	285	252
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE GROUP.

Bibi-Eibat—(*contd.*)

Year.	Group No. XIX.						Group No. XX.					
	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
1896	11	32,301	2,936	144·0	203	103	7	30,816	4,402	145·0	194	96
1897	10	23,604	2,360	145·7	224	70	7	22,853	3,264	160·2	203	96
1898	11	56,350	5,122	164·4	229	70	9	8,845	982	178·6	242	96
1899	16	32,499	2,059	169·6	252	70	11	12,854	1,168	180·7	242	106
1900	26	34,191	1,315	180·6	252	70	14	15,868	1,133	176·5	252	106
1901	31	33,757	1,088	181·0	252	64	13	13,260	1,020	197·9	252	158
1902	32	30,142	942	193·9	279	103	16	27,686	1,730	206·6	273	158
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE GROUP.

BINAGADI.

	Group No. XXV.						Group No. XXVI.					
1896	1	24	24	30·0	30	30						
1897	4	197	49	65·2	129	30						
1898	4	228	57	65·2	129	30						
1899	6	163	27	67·0	129	30	2	50	25	36·0	42	30
1900	8	118	27	68·3	176	30	4	166	4	49·0	62	30
1901	9	171	19	73·4	176	30	4	297	74	48·5	62	30
1902	9	115	13	73·4	176	30	6	374	62	75·8	132	63
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

ZABRAT.

	Property No. 70.						Property No. 72.					
1902	1	73	73	131	131	131	1	229	229	131	131	131
1903												
1904												
1905												

	Property No. 71.					
1901	1	430	430	125·0	125	125
1902						
1903						
1904						
1905						

PRODUCTIONS FOR EACH SEPARATE PROPERTY.

GROSNY.

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	Ermoloff, no No. (Ackverdoff).						**No. 24.**					
1899	13	4,161,400	320,108				1	51,000	51,000			
1900	11	2,075,600	188,691				1	59,000	59,900			
1901	7	1,949,900	278,557		74	178	4	1,735,200	438,300		114·0	157·3
1902	8	11,258,300	1,407,287		74	229·7	4	438,600	109,650		108·9	157·3
1903												
1904												
1905												
	No. 977.						**No. 975.**					
1899	8	9,244,600	1,155,575				5	6,039,600	1,207,920			
1900	9	6,694,300	743,811				10	4,376,900	437,690			
1901	10	5,419,700	541,970		54	142·3	8	2,262,900	282,863		89·0	155·6
1902	10	2,244,100	224,410		54	142·3	12	1,439,600	119,966		96·4	189·0
1903												
1904												
1905												
	No. 22.						**Ermoloff, no No.** (Anglo-Russian Maximoff Co.)					
1899	2	138,500	69,250				9	1,870,320	207,813			
1900	2	298,200	149,100				11	3,495,290	317,754			
1901	1	116,400	116,400		157·7		9	5,799,150	644,257		106·3	167·6
1802	1	133,500	133,500		157·7		10	5,053,703	505,370		106·3	246·1
1903												
1904												
1905												
	No. 23.						**Grosny, no No.** (Moscow Oil Co.)					
1899	2	537,400	268,700				7	1,862,645	266,092			
1900	5	1,616,800	323,360				9	1,210,501	134,500			
1901	5	2,572,600	514,520		70·6	105·6	3	481,700	160,567		131·0	156·0
1902	5	703,400	140,680		70·6	105·6	7	778,230	111,176		131·0	245·8
1903												
1904												
1905												

PRODUCTIONS FOR EACH SEPARATE PROPERTY. GROSNY—(*contd.*)

Year.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.	Number of productive wells.	Production of oil.	Average production per well.	Average depth of wells.	Maximum depth of wells.	Minimum depth of wells.
	No. 976.						**No. 32.**					
1899	4	1,026,581	256,645									
1900	6	1,056,924	176,154				2	232,150	116,071			
1901	5	490,260	98,052		111·0	216·0	2	757,036	383,518			
1902	6	776,880	129,480		111·0	264·0	2	544,954	272,477		231·4	233·9
1903												
1904												
1905												
	No. 10.						**No. 12.**					
1899	1	230,520	230,520									
1900	6	1,057,815	276,303									
1901	6	2,024,495	337,716		100·9	196·6	1	215,586	215,586		114·0	114·0
1902	9	1,254,360	139,374		129·0	185·7	1	1,882,244	1,882,244		114·0	114·0
1903												
1904												
1905												
	No. 15.						**No. 11 A.**					
1899	1	32,000	32,000									
1900	7	2,441,000	348,728									
1901	13	6,557,494	504,423		90·9	167·6						
1902	16	3,885,230	242,827		90·9	215·7	2	738,333	369,166		115·7	172·5
1903												
1904												
1905												
	No. 16.						**No. 11 B.**					
1900	4	5,472,000	1,368,000									
1901	11	4,076,688	370,608		104·3	183·1						
1902	12	1,391,113	199,326		104·3	304·9	1	149,551	149,551		123·3	123·3
1903												
1904												
1905												

APPENDIX B.

EXTRACTS FROM THE RULES AND REGULATIONS DEALING WITH THE RUSSIAN OIL INDUSTRY.

Regulations relating to: The exploitation of private land—Prospecting on Government land—Leasing of Government land for exploitation—Government land known to be petroleum bearing—Conditions on which Government and private land may be exploited—Oil pipe-lines—General rules for conducting underground work by mine owners—Special Government control for underground work—Action of officials and instructions of mining administration if mining regulations not adhered to—Hire of workmen for private mines and factories—Penalties and fines for inattention to rules—Hire of workmen for factories—Hire of persons under age—Employment of persons under age and women—Special regulations relating to relationship between employer and workmen—Control of oil in the Caucasus—Technical regulations compulsory to oil producers in the Caucasus—Controlling oil streams—Regulating streams of oil from bailing well—Ditto from fountain wells—Laws dealing with fountains—Instructions of Technical Commission—Precautions against fire—Extinguishing fires—Enforcement of regulations—Oil producers' meetings—Regulations for leasing Government lands for exploration and exploitation without auction.

SECTION I.—THE EXPLOITATION OF PRIVATE LAND.

ART. 541. The exploitation and production of petroleum on properties owned by private individuals or companies, or on ground adjoining factories under Government protection, is allowed to the owners or persons who have entered into an agreement with the proprietors of these lands.

Art. 542. Land which has been given to the peasants of different classes to purchase on instalment system can also be leased, provided the regulations, which are described in a separate supplement to the laws on properties (second half of rules for acquisition of lands, Art. 162), are adhered to.

Art. 543. The exploitation and production of petroleum on land which has been granted by the State to peasants and other settlers, but not given with full possession, is subject to the same rules as those referring to Crown properties, but with the provision of compensation to peasants for cession of lands laid down in Art. 201—

Additional rule (1890). The Minister of Agriculture and Domains has been authorized—

(1) In conjunction with the head of the Civil Service Department in the Caucasus, to formulate rules and regulations—

(*a*) For the recovery from the peasants of the Apsheron Peninsula, of the land which is found to be oil-bearing.

(*b*) For payment of compensation for their ceded land.

(*c*) For granting temporarily to people deprived of their former possessions such land as is not adapted to immediate petroleum exploitation purposes.

(2) To lay down a system for collecting the royalty from ground under exploitation, this royalty being arranged between the peasants of the Apsheron Peninsula and the lessees, with the sanction of the Government; also to leave in force agreements not strictly in accordance with Art. 201, but probably not requiring any alterations of the irregular points.

Art. 544. The prospecting and exploitation of oil on Crown lands may take place according to the regulations of Arts. 557-593.

Remarks issued in 1895—

(1) Plots of Crown land leased in accordance with paragraph 17 of the supplement to Art. 449 of the Forest Laws are not available for oil exploitation.

(2) The regulations referring to oil exploitation in the districts of the Cuban and Terek Cossack Army follow further on.

Art. 545. The Minister of Domains is authorized to issue regulations for prospecting and exploiting oil lands on lands covered by valuable forests, and in cases of necessity to fix a sum to be deposited by the lessee as a security for the fulfilment of these regulations which deal with the preservation of the surface ground and forests.

Art. 546. All the oil-bearing land which has been predestined by favour of Majesty for granting to private persons is henceforth to be retained in the possession of the Crown, together with a certain area necessary for the work connected with petroleum production.

Art. 547. All persons having civil right within the limits pointed out in Arts. 264–266, and in paragraphs 1, 2, 5, 7 of Art. 266, 268, and 269 are allowed to exploit oil.

The following rules were temporarily issued in 1895:—

(1) Subjects of Jewish creed having the right of residence without the pale, foreigners and foreign companies entitled to operate in the Russian Empire, and Russian companies formed on shares with warrants to bearer, will be henceforth permitted to acquire under lease or full possession oil-bearing land, hereditary properties excepted, also to prospect and obtain by lease surveyed plots in the Caucasus. In all cases, however, the sanction of the Minister of Domains, in conjunction with the Ministers of the Interior and Finance, and the head of the Civil Service Department in the Caucasus, must be applied for.

(2) Foreigners and Jews mentioned in the first part of this article are now allowed to hold full power of attorney for managing petroleum properties in the Caucasus, but this does not apply to powers of attorney given to persons prior to the publication of this regulation.

(3) All transactions made with the intention of avoiding this regulation will not be legal.

(4) A list of plots coming under the operation of these laws will be prepared by the Minister of Domains, with the assistance of the Minister of the Interior, and the head of the Civil Service in the Caucasus, for presentation to the Senate, with the object of publication for general information.

Remark 2.—Persons mentioned in Arts. 264–265, also in paragraphs 1, 2, 5, 7, of Art. 267, having acquired oil-bearing land prior to the issue of the regulations on petroleum exploitation, which obtained Imperial sanction on 3rd June, 1892, and explained in Arts. 541 and 615 of this code, are entitled to continue their work on the plots already in their possession.

Art. 548. Those who do not possess the legal right to produce petroleum, and such as have been deprived of that privilege, are compelled to sell or part with their plots, either in full possession or by lease, within two years, the former from the time of acquisition, the latter from the day their right has been cancelled, otherwise those plots belonging to the Crown are leased to other persons by public sale according to Arts. 589 and 590, referring to this point. The money realized by the auction sale of the property, minus the Government's expenses, valuations, and auctioneering expenses, and the licence due (Arts. 576 and 589), is handed over to the owner of the sold property. These rules apply also to the right of participating in petroleum enterprises.

Art. 549. Private individuals or companies are bound to report to the local engineer of the Mining Department any discovery or exploitation of petroleum on their properties; also owners of land adjoining factories under Government regulations have to do the same, and particulars must be given, stating the size of the plot, and whether the owner will personally exploit it or lease it; in the case of the latter, the name of the lessee and the period of the lease must be stated. In the Caucasus the prospecting and producing of petroleum is permitted on the basis declared in paragraph 2 of Art. 222.

Art. 550. The duties of the local mining office are to use its controlling power—

(1) Over the management of oil wells with regard to safety.

(2) Over the surface and underground plans, as well as statistics of boring work, and on leased Crown lands watch that only petroleum, kir,* and bitumen are exploited.

(3) Over the protection of oil wells.

(4) Over the fulfilment of the regulations for preventing fires on petroleum properties.

(5) To prevent the infringement of the rules relating to the construction and exploitation of oil lines. The engineer of the local Mining Departments should be present at meetings of the producers, and take part in the proceedings of the Baku Technical Society. The department must also arrange for the division of railway oil-tank waggons for transport, according to separate rules issued with reference to that subject, and collect statistics relating to the output of oil.

Art. 551. Any complaints about the action of Government offices or officials have to be lodged in the usual manner in accordance with Arts. 330 and 332, the action referring to the execution of regulations in Arts. 541–615.

Art. 552. In order to ameliorate the grievances of those engaged in the petroleum industry, the Minister of Domains, in conjunction with the head of the Civil Service, is empowered, when necessary, to call general or local meetings of persons interested in it (*i.e.*, producers, refiners, transporters, etc.), and invite representatives of the Mining Departments, railway and shipping companies, a special official appointed by the Minister presiding.

Art. 553. The members of the local meetings of the petroleum industry elect a committee and a technical commission for guarding the mines; an engineer of the local Mining Department must occupy the chair.

Art. 554. Special instructions are issued by the Minister of Domains for the organization, and the subject of discussion at meetings, also for election of a committee and technical commission for protecting the mines.

Art. 555. The producers have to pay to the Government for every pood of oil taken from the plots exploited a tax amounting to $\frac{1}{50}$ to $\frac{1}{10}$ kopeck (Law, 1896; Art. 1166). The money collected in each district forms a special fund, which is employed in improving the district, clearing the oil spouted by fountains, making roads amongst the properties, organizing good medical service, and performing other useful purposes beneficial to the industry.

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* ***Kir*** **is the local term for the solidified oil which has accumulated upon the surface of the ground, and been deprived, by exposure to the air, of its lighter constituents.**

The stipulation of the amount to be charged in each case, and the method of collecting the money, are left to the decision of the local meetings, with the sanction of the Minister of Domains. The power of expending this fund is in the hands of an advisory committee of meetings, and the account is under the direct supervision of the Government.

Art. 556. The Minister of Domains is authorized to decide all questions and misunderstandings that may arise from the enforcement of the regulations referring to the petroleum industry, and to give additional explanations as to the disputed meanings of such laws, general instructions, and special orders compulsory to the oil producers; but these decisions must not relate to questions which are coming under the jurisdiction of the courts of law. All decisions of a compulsory nature must be submitted to the Senate for publication for general information.

SECTION II.—BORING ON GOVERNMENT LAND.

Art. 557. The prospecting for petroleum on Government ground by surveying and exploring without doing any excavation work is permitted, no special application is needed, and no limit of the size for surface prospecting is stipulated.

Art. 558. Persons desiring to commence exploitation work on a certain plot, and having the right to cut trees which prevent the boring work from proceeding, are bound—

(1) To stipulate the particular plot by fixing in the ground a peg with their initials and the date.

(2) To send, within seven days after fixing the peg, to the office of the local Department of Domains an application for a prospecting licence, and state therein the size of the plot, the name of the place, the distance of the peg from a fixed point, and other details of the chosen plot.

Art. 559. The prospecting licences are issued for a period of one year.

Remark 1.—In districts inhabited by a small population this licence can be extended to two years. The lists indicating such places are made by the Minister of Domains and sent to the Senate, who publish them for general information.

2.—In special circumstances the period of one year in the ordinary districts may be prolonged to two years, and places with a small population to three years.

Art. 560. From the day of issuing the licence the area of 90,000 square sagenes, reckoned 150 sagenes north, south, east, and west of the fixed peg, is recognized as a claim for exploitation, and no other person is allowed to fix a peg on this particular strip.

Art. 561. Two claims cannot be granted to the same person separated by less than 2 versts.

Art. 562. For the right of prospecting, a royalty is charged for each dessiatine; the amount is paid when taking out the licence, and the figure is fixed yearly by the Minister of Domains, but cannot exceed 5 roubles a dessiatine.

Art. 563. The ground which has been leased for exploitation comes under the supervision of the local Mining Department. The local Department of Domains, however, is responsible for the fulfilment of the regulations concerning forests and for the collection of taxes for surface use.

Art. 564. The manner of exploring is left entirely to the discretion of the lessees, but the produced oil cannot be taken away from the explored area.

Art. 565. Lessees who decide not to proceed with the producing of petroleum have to report to the local Mining Department after termination of exploitation.

They are bound to vacate the ground within a certain defined period allowed for exploitation (Art. 559), and leave the casing in those wells which the local mining engineer may consider adapted for further development.

Such a property, unless distinctly declared as oil-bearing, is again thrown open for public exploitation, and is placed once more under the supervision of the local Department of Domains.

Art. 566. During the exploitation those regulations must be enforced which are explained in remarks to Art. 272, and in Arts. 275, 276, 278, 280, remarks to Art. 281, and Arts. 282, 286, 598, 601, 605, and 606.

SECTION III.—LEASING OF GOVERNMENT LAND FOR PETROLEUM EXPLOITATION.

Art. 567. Explorers wishing to commence working on a property are entitled to apply for a portion of the explored area.

Art. 568. Application for exploiting land must be handed in to the office of the local Mining Department before the expiration of the exploitation licence (Art. 559). The application must be accompanied by a section specifying the supposed formation of the ground, and by two copies of the plan representing the plot asked for, pointing out the position of the peg and the work done.

Art. 569. The local Mining Department, after receiving the application, grants to the applicant or his representative the lease of the ground requested, subject to the payment of the expenses connected with the transfer of the deeds, according to the rules dealing with the subject.

Art. 570. The notice to an absent applicant must be issued at least four months prior to granting the lease, and should he fail to appear personally or to be represented by another person at the appointed time, he loses the right of possession of the surveyed plot. His peg is removed, and the claim is declared free for public application, and the supervision of the plot is left again to the Department of Domains.

Art. 571. The size and direction of the claims may be decided by the applicant with the following restrictions:—

(1) The area cannot exceed 10 dessiatines, nor be less than 1.

(2) The surveyed plot should, where possible, be rectangular.

(3) The width of the plot cannot be less than one-third of its length.

(4) The space left between the leased plots may not be less than 1 dessiatine, and must correspond with the third clause of this article.

Art. 572. When granting a lease, the land must be surveyed by the district mining engineer, and a plan must be drawn which shows particularly the dimensions in sagenes.

A copy of the document examined and confirmed by the office, under whose control the space in question lies, is given to the applicant, the original retained at the office, and another copy is forwarded to the Mining Department.

Art. 573. After the lease has been granted, the lessees are compelled within two months to clear the portion of the area which does not comprise the plot granted to them, and must leave all casing in bore-holes which are considered by the mining engineer of the local Department as suitable for further developments. If, on the contrary, no definite information is forthcoming as to the value of the land, the plot is returned to the Department of Domains, and declared free for public application.

Art. 574. After receipt of the deeds for the leased land, the lessee is entitled to produce asphalt, bitumen, and petroliferous products, and may dispose of them as he wishes, and may erect buildings and works necessary for the production of oil.

Art. 575. Arts. 296, 302, 306, 308, and 309, with accompanying Remarks 310 and 315, apply to plots leased for oil exploitation.

Art. 576. For the use of the leased plots for the production of oil, the lessees must pay to the local office of the Treasury a tax for each dessiatine, the amount of which is fixed by the Minister of Domains for 12 years in advance.

Remark 1.—In the Pechorsk district, as well as Saghalien Island, the Minister is authorized to exempt the producers in special cases from payment of the tax for a maximum period of 5 years, provided this measure is recommended by the local authorities.

(2) The mining tax in the Caucasus remains according to the former regulations, until February 1, 1896, and is equal to 10 roubles a dessiatine.

Art. 577. The tax must be paid by the lessees to the local office of the Treasury for 6 months in advance, from January 1 to July 1. Those who have occupied the plots after these dates must pay the balance due to the next half-year when taking out the deeds.

Art. 578. In cases of non-payment of taxes when they become due, the lessees are allowed to fall two months in arrears, but are charged interest on the outstanding amount at the rate of 10 per cent.

Art. 579. The amount of the tax and fines must be presented to the office of the local Mining Department.

Art. 580. If a settlement of the tax is not made after two months' arrears, a double tax is levied, but without interest, and an interdict on the plot and fixtures is ordered.

The overdue tax may be realized by the sale of a portion of the stock, instruments, or buildings which will cover the debt, according to Arts. 1027 and 1143 of the Civil Laws. If the amount realized by the sale is insufficient to discharge the debt, the plot itself is offered for public auction, and should there remain a balance in favour of the owner, this is handed over to him; but should there be a deficit, he must cover it.

Art. 581. The sale is cancelled if prior to its commencement the full amount of the tax and fine is paid.

Art. 582. Should there be no purchasers for the plot and no sale be effected, the same is declared free and placed under the control of the Government, with all the works and buildings thereon, and without any compensation to the former exploiter; but he is still held responsible for any deficit found after realization.

Art. 583. Plots are generally declared free if the lessees who have received them by pegging do not commence exploitation after 2 years; but if proof is given that the lessee has spent a considerable sum on preliminary works, a postponement of 2 years more is granted. The plot is declared free if after 4 years a stoppage is made without very good reasons.

Art. 584. Freed plots are given to persons who wish to produce petroleum according to Arts. 589, 590, and 593.

Art. 585. The use of oil-bearing ground ceases if the results are unsuccessful, or if the lessee refuses to continue exploitation, or the wells are drained. In such cases the lessee must report to the local Mining Department, and return the documents and clean the property within one year, and he must leave the casing in those wells which the mining engineer may deem suitable for further development.

SECTION IV.—GOVERNMENT LAND KNOWN TO BE PETROLEUM-BEARING.

Art. 586. The exploitation of Government land known to be oil-bearing is prohibited. A list of such ground is made and altered from time to time, as occasion demands, by the Minister of Domains, and is published by the Senate for general information.

Art. 587. Government oil-bearing land is divided according to the discretion of the Minister of Domains into plots suitable for oil exploitation, but the size cannot be less than 1 dessiatine nor exceed 10 dessiatines. These plots are leased to private persons for exploitation, or offered by public auction, except in the case explained in Art. 593.

Art. 588. A plan of each plot is prepared by the local Mining Department. The ground is valued, and, if necessary, a compulsory minimum annual production of oil is stipulated in accordance with the instructions issued by the Minister of Domains.

Art. 589. The oil-bearing lands are leased by auction according to the decisions of the Minister of Domains, either on the basis of a single payment, or on a royalty charged on each pood of oil produced, a compulsory minimum annual yield being stated. The auction commences by bids for the value of the ground, and is followed by the amount of royalty per pood.

Art. 590. Until further alterations, the auction for leasing Government oil-bearing land must take place in the presence of representatives of the Ministers of Domains and Finance, and be under State control. The tenders must be sealed and the following instructions observed:—

(1) Notice for tenders must be advertised not later than six months before the auction.

(2) The price or royalty offered in the sealed tenders must not be less than the limit stated in the advertisement calling for tenders.

(3) Persons who have tendered must deposit an amount representing one-tenth of the whole amount, or one-tenth of the royalty, to get which figure of the latter, multiply the quantity of minimum compulsory annual yield by the rate of the royalty.

(4) The plot is leased to the person who makes the highest bid or rate of royalty, and has complied with all the conditions. In case the tenders are equal in value, lots are drawn, and if all the tenders are personally represented, the representatives themselves draw, or for those absent the president of the assembly draws. The confirmation of the sale follows in the usual way.

Art. 591. A person, after obtaining a plot by tender for a single payment for ever, must pay the full amount within 2 months, and his deposit, left when tendering, is returned to him. If the plot is leased on a royalty basis, the lessee must appear within a month from the day of receiving the plot to conclude an agreement, and pay in addition to his deposit a balance which will, together with the deposit, equal a sum equivalent to half the annual royalty. If the full amount named in the tender is not paid, nor the deposit increased to the required sum, the deposit is forfeited and added to the State revenue, and the person loses his claim to the plot.

Art. 592. The royalty per pood is paid half-yearly in accordance with the quantity of petroleum yielded and shown in the statistics, but should the output not reach the limit, the lessee must pay the difference in order that the Government revenue may not fall below the sum tendered for.

An exception is made in the first year of the lease if the production does not reach the limit, when a settlement is arrived at by a payment of 50 per cent. of the difference.

The deposit is always retained so long as the plot is exploited, and the lessees are responsible to the extent indicated in Arts. 580–582 to the State Treasury for overdue payments. The instructions and regulations referring to registration of the output are defined by the Minister of Domains in conjunction with the State Controller.

Art. 593. If after three times a public auction of Government land results in no purchase, it may be leased to private persons without public sale. The terms will be either a single payment of the estimated value or a royalty per pood, the rate and limit of which are fixed by the Minister of Domains.

Should there be no offers for leasing Government land in this way, it may be employed for other purposes.

SECTION V.—THE CONDITIONS ON WHICH GOVERNMENT AND PRIVATE LAND MAY BE EXPLOITED.

Art. 594. The exploitation of Government or private oil-bearing ground is permitted only where the size of a plot is not less than 1 dessiatine, and with a width not less than one-third of its length.

Remark.—This law does not apply to those plots which have been acquired prior to the issue of regulations dealing with petroleum production, sanctioned on June 3, 1892, and explained in the Arts. 541–615 of the code. If such plots are less than 2 dessiatines they cannot be reduced any more.

Art. 595. The erection of refineries and other factories for the treatment of crude oil, if not directly connected with bailing, pumping, or storing of oil, is allowed by the Minister of Domains if a special application is made. The regulations defined in Art. 890 of the Excise Laws must be strictly observed. In cases of enlargement or extensive alteration of these factories, the decision is left in the hands of the Mining Department.

Art. 596. The owners of oil-bearing land are compelled to allow neighbours to excavate on their properties, canals, and waterways for a reasonable remuneration, and it is for the Mining Department to decide whether the measure is urgently required by the one, and not inconvenient to the other owner. If no understanding can be arrived at between the two parties, the local Mining Department, acting upon the invitation of the technical commission, stipulates the rate of the remuneration (Art. 553).

Art. 597. Oil producers are not permitted to close roads running through their plots before the district Government engineer has given his opinion as to whether such a measure would be against the interest of neighbours. All roads shown on the plan of his plot must remain open, unless authority is obtained to close them.

Art. 598. The system of exploiting oil is left entirely to the producer, but he must—

(1) Observe all regulations relating to mining and general underground work, prevention of fires on oil properties, and comply with all instructions issued by the Minister of Domains in reference to the mining industry.

(2) Draw a plan of his property, showing all boring and constructional work.

(3) Admit Government officials entrusted with the control of oil properties, for inspection of boring and constructional work connected with the storage and exploitation of petroleum.

(4) Furnish the Government with full statistics on demand.

Art. 599. Oil producers are compelled to provide their employees with medical attendance.

Art. 600. Before commencing boring work, the producer must make a report to the local office of the Mining Department, and deliver up a plan of the area where the well is to be bored, and give other details of the intended operations.

Art. 601. The producers proceeding with boring work for the exploitation of petroleum are compelled to keep a journal according to the prescribed form, and to prepare drawings of the different kinds of strata passed. They must also comply with all instructions given by the Government district engineer referring to the safety of the work, and the lives and health of employees, and to fires and means of supporting wells.

Art. 602. Producers are bound—

(1) To have prepared all safety arrangements for removing the oil spouted by fountains, and all instruments for relief work.

(2) To immediately take all precautions on the first signs of a fountain.

(3) To report to the Government district engineer the spouting of a fountain.

Art. 603. On receipt of information, or on the appearance of a fountain, the district engineer examines the safety measures which have been adopted by the owners, and if he considers such precautions to be inadequate for the removal of the spouted oil, he may, in conjunction with the Technical Commission, issue instructions for checking the stream of oil. If the proprietor refuses to take the necessary steps, the district engineer may order the relief work to be undertaken at the owner's expense.

Art. 604. If a fountain cannot be regulated by the owner, or even at his expense, all the relief work, such as pumping and storing of the oil, is carried out at the expense of the general fund (Art. 555).

(1) All tools and instruments obtained for the general use of oil producers, and necessary to deal with the controlling of fountains, portable steam boilers, pumps and pipes for pumping the oil into reservoirs, are provided by this fund.

(2) The labourers engaged at this work are paid by it.

(3) Reservoirs, ambars, tanks, etc., are constructed on the account of the before-mentioned fund.

(4) The regulations and conditions for the use of these works, and the rate of charge for the temporary storage of the oil, are fixed by the Minister of Domains.

Art. 605. To prevent damage to the upper oil strata from flooding with water, etc., the abandoned wells must be filled up with clay after the casing has been removed.

Art. 606. The district mining engineers when giving oil producers advice for the precautions to be taken during work, to prevent fires, and for regulating fountains, must be guided by the instructions of the Minister of Domains on the subject, and by the resolutions of the Technical Commissions (Art. 553).

Art. 607. Oil producers must execute any instructions of the district engineer, at the date fixed, otherwise the boring or exploitation may be stopped. If the producer then fails to comply, the district engineer may order the work to be carried out at the owner's expense.

SECTION VI.—OIL PIPE-LINES.

Art. 608. The laying of pipe-lines for local requirements is left to the producers and to people who have the authority to deal in petroleum.

Art. 609. For the construction of pipe-lines, permission is required from the local authorities. No ground is specially granted for them, but plots are allotted for the pipe-line stations, guard-houses, and other necessary constructions, their size being limited to the actual requirements.

Art. 610. The laying of pipe-lines and the erection of the necessary accessories is not allowed—

(1) On ground used for gardens, plantations, yards, and buildings, unless the permission of the owner is first obtained.

(2) On plots leased by the Crown for petroleum exploitation, without the sanction of the lessees. The construction of pipe-lines, stations, or reservoirs is not allowed within 100 sagenes from buildings without the permission of the owner of the buildings.

Art. 611. For the laying of pipe-lines and the allotment of ground required for constructions no charge is made—

(1) On Crown lands which are not subject to general taxes and not under cultivation by peasants.

(2) On bare areas not adapted to agricultural purposes, which are left for the use of peasants (under the Crown's protection), but not transferred to them.

(3) On the boundary of plots leased by the Government for oil production.

(4) Along main and branch roads and their crossings.

Note 1.—When constructing pipe-line stations, reservoirs, or guard-houses on Government ground, the producer must give a written declaration that, in case such land is transferred wholly or partly to a private individual, he will remove all the pipes within a certain time, and place them on the border of the new divided groups, provided no arrangement with the new owner can be arrived at to leave the lines in their former position.

Note 2.—The pipe-lines along main roads and their crossings must be laid on the sides, and not in the middle, where the traffic would be inconvenienced.

Art. 612. The laying of pipe-lines and the allotment of ground for the necessary constructions can be undertaken—

(1) On Crown lands subject to the general taxes.

(2) On properties of private persons and such belonging to town administrations or peasants, on a conclusion of arrangements with the owners of the ground. If no agreement can be arrived at with the owners, and if there are no means of changing the direction of the pipe-lines without considerable expense and large extension of the line, the producer may apply to the Government for a permit to lay pipes over the disputed ground, and occupy space essential for construction work, regardless of the owner's permission, but must pay an annual rent until it is found expedient to remove the line.

Art. 613. The amount of rent to be paid to the owners is fixed according to Arts. 582, 584–588, 596, 598, 602, 605, and 608 of the Civil Laws if no agreement can be concluded.

Art. 614. The rent for the pipe-lines laid on leased Government land is paid to the lessee until the term of his lease expires, and if the ground is transferred to another person, the question as to who shall receive the rent is decided by the conditions under which the ground has been re-leased.

Art. 615. The owners of pipe-lines are compelled to compensate the proprietors of ground for any damage done by the lines or construction works.

SEVENTH PART.—REGULATIONS FOR CONDUCTING UNDERGROUND WORK BY MINE OWNERS.

SECTION I.—GENERAL REGULATIONS.

Art. 714. The conducting of underground work by mine owners on whatever ground it may be is subject to the regulations in Arts. 715–740.

Art. 715. Mine owners must notify in every case the Government Offices or the officials responsible for the control of private mining enterprises, their intention to begin, recommence, or to shut down operations. They must report any danger expected, or occurrence of accident, and it is necessary to distinctly point out the place of works.

Art. 716. Mine owners must inform the district engineer of the appointment of a responsible person for the management of the property, or any change in the appointment of such a person.

Note.—In the Government of Poland, from January 1, 1898, only Russian subjects may be appointed managers of mines with full responsibility.

Art. 717. Mine owners are compelled to keep a correct plan of the mine developments, and must conduct the work in such a way that no danger can arise with regard to life, and health of workmen and surrounding population, to buildings and other property, to roads of communication, to mineral and other springs required for the water supply of the inhabited areas.

Art. 718. A detailed guide for precautionary measures to be adopted for the safe conduct of underground work compulsory to mine owners and miners is issued by the Minister of Domains. Such guide must first be submitted to the Scientific Mining Committee for consideration, and must contain full particulars with regard to the support of excavated spaces, and the filling of same with ordinary soil when exhausted, also concerning signals, exits from mines, lowering and raising workmen and materials, use of explosives, boilers and machinery, protection of human life and animals from falls, prevention of fires, danger from the accumulation of gases and water in the mines, ventilation, special conduct of work near railways and roads, also near mineral and water springs used by the local population.

Art. 719. Mine owners must inform Government officials to whom the control of mines has been instructed, and allow them to inspect the works, and assist them at their inspection, and carry out all legal instructions given by them.

Art. 720. In the case of a catastrophe on an adjoining property, mine owners must render full assistance in the work of relief.

Art. 721. With reference to the inspection of mining operations, and concerning their safety and working, the mining concerns are divided into considerable and less considerable ones. The division into classes upon the nature of work conducted, the number of workmen employed, etc., is made by the Mining Administration or Department.

Art. 722. Responsible managers of large concerns must possess the required knowledge of mining (Art. 716). This knowledge is confirmed by mining engineers diplomas, by testimonials from mining schools or the mining department of industrial schools, and by certificates issued to persons who passed the mine managers' examination described in Art. 178 by a Commission.

Note.—The Commission appointed for mine managers' examination (of persons who have no diploma or certificate of any mining school) consists of the district engineer, Government surveyor, and other persons appointed by the local Mining Administration or Department. Admission to the mine managers' examination is granted to persons who have been engaged in mining work for at least three years, or to such as hold a certificate from foreign mining schools. The method of the examination is arranged by the Scientific Mining Committee, confirmed by the Minister of Domains, and published for general information.

Art. 723. The regulations specified in Art. 722 can also be applied in case of necessity to smaller concerns if such are situated close together, and could be amalgamated for the engagement of one responsible mine manager.

Art. 724. Such large mining businesses which will be recognized by the Mining Administration or Mining Department as dangerous (containing explosive gases, self-burning coal, enormous quantities of water) may be, distinct from the obligations indicated in Art. 732, put under a special Government control according to Arts. 727–730.

Art. 725. An appeal can be lodged with the Minister of Domains against the decision of the Mining Administration or Mining Department, stipulating a certain mining trade as dangerous, and after the opinion of the Scientific Mining Committee has been secured, the Minister settles the question definitely.

Art. 726. The Minister of Domains is authorized from January 1, 1894, to enforce all the rules given in Arts. 722–730 and 733 and 734 in the different parts of the Empire, with the exception of the territory belonging to the Cossack Army of the Don. The regulations must be enforced gradually, as the local conditions of the country may allow it and make it expedient.

Remark.—In 1880 it was decided that the regulations mentioned in Arts. 714, 715, 717, and 720, 731, 739, and 740 should not be applied to mining enterprises in the territories of the Cossack Armies.

The enforcement of them has been, however, extended to private mining enterprises in territories of the Orenburg, Terek, and Cuban Cossack Armies.

SECTION II.—SPECIAL GOVERNMENT CONTROL FOR THE CONDUCTING OF UNDERGROUND WORK.

Art. 727. For every mine recognized as dangerous for exploitation, the Mining Administration or Mining Department can issue in addition special bye-laws (Art. 718) referring to the obligations of employees, to the system of work, to the surveyor's drawings, to the use of explosives, to the organization of signals, and other details. With regard to protests against such bye-laws, the mine-owners have to observe the formalities stated in Art. 725.

Art. 728. If several plots recognized as dangerous for exploitation are under the supervision of one responsible person, there must be, notwithstanding, on every one of them a special responsible foreman who would respond to the requirements explained in Art. 722.

Art. 729. The Mining Administration and the Mining Department are entitled in case of urgency to demand from the owner of a dangerous plot the appointment of a mining engineer as a responsible party.

Art. 730. The Minister of Domains has the right, on the suggestion of the Mining Administration or Mining Department, to appoint a special mining inspector for the permanent control of those mining concerns where the exploitation is attended with danger.

It is also left to the discretion of the Minister to apply this measure to every extensive enterprise, although not recognized as exposed to danger, if, owing to the neglect of the administration, a serious accident has occurred to the workmen. The provisions for the appointment of special inspectors, explaining their rights and obligations and payment of salaries, are explained by Arts. 108 and 109, and in the Remarks to the latter article.

SECTION III.—ACTION OF OFFICIALS AND INSTRUCTIONS OF THE MINING ADMINISTRATION IN THE EVENT OF MINE OWNERS NOT FULFILLING THE REGULATIONS REGARDING MINING WORK.

Art. 731. In the event of mine proprietors not fulfilling the regulations stated in Arts. 714–730, the Mining Offices and officials act in accordance with Arts. 732–740, which follow.

Art .732. The Mining Offices and officials, when pointing out to the producers any defect in the conduct of the work, and suggesting alterations, make an entry of it in the book specially provided for this purpose by the mines, demanding the execution of the improvements within a certain time.

Art. 733. The district engineer has the power to instruct mine owners to discharge immediately their responsible managers if such do not act according to the regulations of Arts. 722 and 729 and remark to 716. Equal right is given to the Mining Administration and Department concerning responsible managers answering to these regulations if the district engineer certifies the inability and non-reliability of such persons.

Art. 734. In the event of mine proprietors failing to comply with the regulations of Arts. 722, 728, 729, 733, and remark to 716, the mines may be shut down by the Mining Administration or Department until the faults have been rectified. If the regulations of Arts. 728 and 729 have been contravened, but can be justified by reasons of vital importance, the Mining Administration or Department can allow, with the sanction of the Minister of Domains, an extension of time not exceeding three months for rectification.

Art. 735. If mine owners do not comply with the instructions of the Mining Offices or those of the officials referring to any defects in the underground workings (Art. 732), the official who has the control of the mine in question draws up a protocol according to Art. 1311 of the Criminal Code, and presents same to the Office for Mining Affairs. The defendant has a right to send in a declaration.

Art. 736. After the investigation of the protocols, referred to in Art. 735, is made, and in case of necessity new information added to complete the charge, the Office for Mining Affairs may levy a fine not exceeding 50 roubles.

The hearing of the case must take place not later than three months from the date of presentation of the protocol. The money fines levied for contravention of these articles are to serve for the foundation of a special fund used for rendering assistance to sick and disabled miners. This fund is under the supervision of the Domain Ministry, represented by the Mining Department.

Art. 737. Appeals against the decisions of the Office for Mining Affairs must be lodged with the Minister of Domains within one month of the passing of the sentence.

Art. 738. In case mine owners are unable to pay the fine levied by the Office for Mining Affairs, they cannot be punished by imprisonment (Art. 84 of Criminal Code).

Art. 739. If after being fined twice mine owners do not comply with the instructions of the respective Office or officials, a notification must be made to the head of the Department concerning the necessity of rectifying the omission at the owner's expense, and if sanction is obtained, the outlay for the execution of the work is collected from him in the usual course.

Remark.—Should there be imminent danger, owing to the owner's neglect to repair a fault, the officials have power to commence the required alteration before legal proceedings have been taken (Art. 736), on their own responsibility and at owner's expense.

The district engineer is entitled, in case the statement of the Government surveyor shows that the mine owners do not observe the rules referring to plans for mining work, to entrust to the surveyor the drawing of a plan or to add any omissions on the plan at the proprietor's expense, and at a rate fixed by the Minister of Domains.

Art. 740. If, for prevention of danger, final closing or provisional interruption of mining operations should be deemed urgently necessary, a rule may be made by officials on the spot, in the presence of the owner or his representative, and of at least two witnesses. Such rules are presented to the head of the Office who has the control of the district private mining enterprises. This Office and its officials have the power to order the closing or interruption of work, and appeals against such orders must be sent to the Minister of Domains, and subsequently to the Senate (1st Department).

HIRE OF WORKMEN FOR PRIVATE MINES AND FACTORIES.

Art. 647. The hire of workmen for private mines and factories, with the exception of gold-mines, cutting down forests on mining areas, coal-mines, floating timbers, transporting different materials, as well as the mutual relations between workman and mine or factory, are subject to the regulations in Arts. 86–121 and 121–155 of the Industrial Code (issued in 1893), with alterations and additions in the following (648–659) articles.

Remark.—On mining factories and properties non-compliance with instructions besides those named in Art. 146 of the Mining Laws constitutes an infringement of the rules relating to dangerous work.

Art. 648. The powers and obligations of factory inspectors and of district offices for industrial affairs, also of the Ministry of Domains, are explained in Arts. 86–121 and 128–155 of the Industrial Code referring to private mining concerns, and are transferred to district Government engineers or their assistants, to Mining Departments, as the case may be.

Art. 649. The management of mining businesses is not allowed to enter into agreements with workmen, the fulfilment of which extends 12 months or longer from the date of signature.

Art. 650. Agreements with workmen cannot contain any clauses restricting the rights of either party to appeal to law courts.

Art. 651. If work is given to a gang of workmen, an agreement must be made in writing, naming all the members of the party and their foreman, the basis on which the workmen must settle amongst themselves, and the conditions of hire; and any change in the staff of workmen or their foreman must be duly notified to the manager.

Art. 652. It is compulsory to supply workmen with account-books. A gang of workmen receives one general book for all members (Art. 651).

Art. 653. Besides the items indicated by Art. 137 of the Industrial Code, it is necessary to enter into the account-book any deductions made by employer for instruments delivered on credit (Art. 654).

Art. 654. With the sanction of the district Government engineer, workmen may be supplied at a figure not exceeding cost price with—

(1) Lighting materials for underground work.

(2) Explosives.

(3) Any other materials and instruments required for mining purposes.

Art. 655. Workmen under age, *i.e.*, those not having reached the age of 15 years, and females are not allowed to be employed for night shifts and underground work. Independently of this, workmen under age are not to work longer than 8 hours a day.

Art. 656. Provisions sold in the shops of mine or factory owners must not be more expensive than the prices fixed by the district Government engineer. When fixing the prices, the engineers are guided by the cost of the goods, expenses incurred for shop-keeping, and by the information obtained from local town or village councils.

Art. 657. When mining work is given under contract to a single person, the keeping of all regulations compulsory on mine managers as to the hire of workmen, basis of payment, etc., falls on the contractor who has engaged the men. In case of non-fulfilment, the contractor is responsible to the same extent as a manager. Should there be any complaint from the workmen hired by the contractor *re* unsatisfactory payment of wages, the managers must investigate the matter, and take measures to stop the evil. If, however, the parties cannot arrive at an understanding, the managers may retain from the contractor a sum equal to the average monthly wages of the workmen who have lodged the complaint. Managers who omit to fulfil this obligation are themselves compelled to satisfy the just claims of the workmen. The sum deducted from the contractor is to be returned to him after an interval of three months, provided no fresh claims are sent in against him.

Remark.—The average monthly wage to be retained is fixed by the district Government engineer.

Art. 658. Mine or factory owners may apply to headquarters for the granting of decorations to artisans, workmen, or other officials employed by them who have made discoveries or inventions.

Art. 659. On private mining concerns, by a mutual arrangement between employers and employees, mining associations may be instituted to decide disputes arising between the workmen, to assist the sick, invalids, and widows and orphans, and to take over the task of improving the morality of the workmen, or any other improvements beneficial to the welfare of the working-classes.

The same regulations as are applied to Government factories must be observed by these associations, but with the exception that the chairman is appointed by the mine or factory owner.

Remark.—The rules connected with the establishment of medical attendance on private mines and factories are described in a separate article.

Art. 660. The Minister of Domains, in correspondence with the Minister of the Interior, is entitled—

(1) To publish the date when the regulations explained in Arts. 647–659 shall be enforced in different parts of the Empire.

(2) To exempt, on the representation of the Office for Mining Affairs, small enterprises from observing the regulations of Arts. 128–155 of the Industrial Code.

PENALTIES AND FINES FOR INATTENTION TO MINING LAWS.

Art. 1264. For non-fulfilment of Arts. 600, 603, and 605, oil producers are, independent of their liability to the Civil Laws, fined as follows :—

(1) For not notifying the commencement of boring operations, for not presenting in due course the plan of the intended work, and for incorrect compilation of boring journals, from 1 to 25 roubles.

(2) For not giving information of the appearance of an oil fountain, for not having arrangements in readiness to regulate the spouted oil, for inadequate support of wells, for leaving the well casing unfilled, or the wells uncovered, from 100 to 500 roubles.

Art. 1265. For non-fulfilment by private mine and factory owners (excepting gold-mines) of Arts. 91–126 and 128–155 of the Industrial Code dealing with the hire of workmen, the guilty persons are fined in accordance with Arts. 153–155 of Industrial Code, and in Arts. 1359 (1) and 1359 (2) of General Code of Laws, also with Art. 51 (4) of the statute *re* penalties.

Art. 1266. For non-fulfilment of instructions given by Officers or officials of the respective Departments in reference to incorrect methods of conducting underground work, and to systems of altering (Art. 732), the accused oil producers are fined a sum not exceeding 500 roubles.

EXTRACT FROM THE INDUSTRIAL CODE.

SECTION I.—THE HIRE OF WORKMEN FOR FACTORIES.

Art. 86. The hire of workmen for industrial factories takes place on the basis of general rules *re* personal hire, with the additions below.

Remark 1.—The hire of workmen for industrial factories in the Governments of Warsaw and certain other places is concluded on the basis of the local general regulations *re* hire, with the additions indicated in Arts. 87–106 of this code and following alterations:—

(1) Factory managers in the Government of the Polish Kingdom are compelled when hiring workmen to demand their passports according to the laws specially issued for this province.

(2) After the expiration of the agreements dealing with the hire, and after receiving from the manager his passport, the workman must vacate the occupied quarters provided for him by the factory.

Remark 2.—The enforcement of the rules explained in Arts. 87–121 and 128–155 extends to private mining enterprises (except gold-mines), also to different works on mining areas, such as cutting trees, dislodging coal, and transporting goods. All alterations and additions named in the Mining Code must be considered. The same rights accorded by these regulations to factory inspectors, district Offices for Industrial Affairs, and Ministry of Finance, are accorded by virtue of this Code referring to private mining concerns, to district engineers, their assistants, to the Office for Mining Affairs, and the Minister of Domains respectively.

Art. 87. The mine or factory managers must demand from workmen, on engaging them, their passports, an exception only being made for persons who are entitled by law to leave their permanent place of abode, without being obliged to take out a passport or a certificate which is subject to a State revenue stamp.

Art. 88. Workmen living in quarters provided by the employers must deposit their passports with the mine or factory manager.

Art. 89. When the term of a passport expires, the managers must apply to the respective headquarters for renewal of same.

Art. 90. When engaging married women or persons under age, who are in possession of a separate passport, no sanction of parents, guardians, or husbands is required.

Art. 91. Mine and factory managers must return the passports to workmen immediately their agreements have expired (Art. 88).

Art. 92. Account-books given to workmen have the same force as an agreement. All the conditions of the engagement must be stipulated, as well as all settlements with the workman, and deductions for incorrect work or neglect of duty.

In agreements between employers and employees, any clause which tends to limit the right of the latter to legal arbitration is not admissible.

Art. 93. The account-book is in possession of the workman, and is presented to him by the Office for necessary entries.

Art. 94. The hire of workmen takes place either for—

(1) A fixed period.

(2) An indefinite time.

(3) Temporarily for the execution of a certain particular work, and the engagement expires when such terminates.

Art. 95. The agreement for an indefinite time allows either party to sever his connection, provided a fortnight's notice has been given.

Art. 96. Before the expiration of an agreement for a fixed period, or before a fortnight's notice has elapsed in cases of an indefinite agreement, it is not allowed to reduce wages by issuing a new scale, to increase the number of working days or hours per day, or alter the regulations referring to shift-work, etc. Neither are the workmen allowed to demand any alterations prior to the expiration of their agreements.

Art. 97. Wages must be paid at least once a month, unless an agreement is drawn up for longer than one month. If, however, the agreement is for an indefinite period, the workmen must be paid twice a month. If a workman has been engaged temporarily for a particular work, he must be paid (with the exception of piece-work) on the day stipulated in the agreement; but if no such clause has been agreed on, he receives his pay on the termination of the work. A special book is to be kept for accounts with workmen.

Art. 98. A workman who has not received his wages when due, through none of his own fault, has the power to demand the cancelling of his agreement by taking legal proceedings. If the claim made by the workman within a month is found to be justified, a decision is granted in his favour, which allows, besides the wages due to him, damages not exceeding—

(1) For agreements of a fixed period, two months' wages.

(2) For agreements of an indefinite time, a fortnight's pay.

Art. 99. The settlement with workmen in coupons, tickets, bread, goods, etc., is prohibited.

Art. 100. When paying workmen, nothing may be deducted from their wages in payment of debts. Deductions from wages for money advanced by employers for supply of provisions and necessary things by factory or mine shops are not classified with debts in the above. Settlements with workmen in cases of money advanced by employers, or when the salary is being withheld by Court, are to be made as follows: On every pay day one-third of the wages may be detained on account if a workman is single, and one-quarter if he is married or a widower having children.

Addition, 1895.—The same scale of deductions is applied for overdue taxes.

Art. 101. The mine or factory managers are not permitted to charge any interest on money advanced to workmen, or accept any gratuities for securities taken over for debts.

Art. [illegible]. It is also prohibited to charge workmen—

(1) For medical attendance.

(2) Lighting of workshops.

(3) Use of instruments at work.

Art. 103. Mine and factory managers can compile rules for their concerns which must be observed by the workmen, but the rules must be posted up in the factory and workshops.

Art. 104. An agreement between employer and employee may cease—

(1) By mutual consent.

(2) Expiration of the fixed date.

(3) By completing the particular work for which the agreement was concluded.

(4) After a fortnight's notice if the agreement was for an unstated period.

(5) If a workman has been expelled by the authorities from the place of his occupation, or if he has been sentenced to imprisonment which prevents him from fulfilling his agreement.

(6) If a workman is compelled to ent[illegible]ilitary or any other public service.

(7) If the respective authorities ref[illegible] to renew his passport.

(8) If the work has been stopp[illegible] to a fire, flood, explosion, etc.

Art. 105. The agreement may [illegible]ded by the manager—

(1) If a workman neglects his [illegible]e days in succession or six days altogether during a month without important ex[illegible] it.

(2) After the absence of an employee [illegible]re than two weeks in succession without satisfactory cause.

(3) If a workman has been commit[illegible] for trial for a crime which may result in a punishment entailing imprisonment.

(4) Through impertinence or bad conduct of the workman, menacing the employer's property, or the personal safety of the managers or employees engaged in the supervision of the work.

(5) If a workman has contracted a disease dangerous to others.

Remark 1.—The reference to bad conduct mentioned in point in Art. 105 (4) comprises, amongst others—

(1) Careless handling of light.

(2) Smoking tobacco, and having matches, pipes, or cigarettes in possession whilst occupied in the factory, workshops, mine, etc., provided the employer shows that these are contraventions of the rules issued by the Office for Industrial Affairs.

Remark 2.—Workmen discharged under Art. 105 are at liberty to institute legal proceedings against the cancelling of the agreement within one month, and if the Court finds their claim justified, a decision for damages is granted for all losses they may have incurred.

Art. 106. Independently of the cases already mentioned in Art. 198, the workman may insist on the cancelling of an agreement—

(1) If he has been assaulted, gravely offended, or badly treated by the employer, his or her family, or his officials who were superintending the workmen.

(2) If the clauses referring to quarters and the supply of provisions have not been adhered to.

(3) Owing to bad health resulting from the work.

(4) On account of the death of the employee's wife, husband, or other member of his family, if it can be shown that the deceased person had provided him or her with means of livelihood.

(5) If one member of the family who was supporting the workman is compelled to enter military service.

SECTION II.—THE HIRE OF PERSONS UNDER AGE FOR WORK IN MINES AND FACTORIES.

Art. 107. The engagement of persons under age of both sexes for working in mines, factories, etc., belonging to private individuals, or companies, or the State, must be conducted according to the following regulations, 108–121.

Art. 108. Children under 12 must not be allowed to work.

Art. 109. Children between 12 and 15 years must not be kept working longer than 8 hours a day; but this does not include meal hours, school-going, and rest. The work must not last more than 4 hours in succession.

Remark 1.—With regard to the general rules for working hours of employees under age quoted in Art. 105, children of 12 to 15 years may be employed 6 hours in succession if the nature of their work requires it, but in this case their day's work must not exceed 6 hours altogether. The mine or factory owner, having in his employ children under age who are working on this system, is bound to notify such cases to the factory inspectors.

Remark 2.—In those industrial enterprises where 18 hours' uninterrupted work is established with only two changes, persons under age may be employed for 9 hours a day, but only 4½ hours in succession.

Art. 110. Workmen under 15 years of age must not be employed between the hours of 9 p.m. and 5 a.m., or on Sundays and holidays.

Remark 1.—An exception to the regulations 109 and 110 is made in the case of those employed in glass factories, where persons between 12 and 15 years may be engaged on night work not more than 6 hours, but on the condition that the workmen will not have to commence work again before the expiration of 12 hours after ceasing night work.

Remark 2.—In industrial factories where an 18 hours' uninterrupted work is established with two shifts, the night shift, during which persons of from 12 to 15 years are engaged, is counted from 10 p.m. to 4 a.m.

Remark 3.—The Office for Industrial Affairs, or where such is not represented, the Governor, or head of police, may permit firms to employ persons of from 12 to 15 years on Sundays and holidays where work in the factory is continued by grown-up workmen.

Art. 111. It is prohibited to give persons under age mentioned in the preceding articles any work which, by its nature, is found to be detrimental to health, or fatiguing. By arrangement between the Ministers of Finance and Interior, a list of factories and of the kind of work is issued, stating in which industries persons under age cannot be employed. This list, confirmed by the Ministers, contains also a limit of age for each branch, and is published by the Senate for general information.

Art. 112. Factory or mine owners are allowed to open schools for the instruction of apprentices, such schools to be maintained either at the expense of one or several factory owners. The order for school attendance and the programme are prescribed by the industrial inspectors in consultation with the director of district schools.

Art. 113. The founder of a school is elected honorary secretary, and for schools opened by several manufacturers the honorary secretary is elected amongst themselves.

Art. 114. Mine or factory owners having in their service persons under age who are not in possession of even one year's school certificate, are expected to give them an opportunity of attending either the factory school or one in close vicinity. The minimum number of hours allowed for that purpose is 3 a day, or 18 hours a week in all.

Art. 115. Where mines or factories have no schools of their own, the industrial inspectors arrange with instructors from the nearest public schools to teach apprentices employed in the factories in the neighbourhood. The hours of instruction are fixed by mutual agreement between the industrial inspector and the director of district schools.

Art. 116. When no arrangement can be completed for teaching apprentices, the industrial inspector applies to the district curator for opening an additional school. The latter must use every means to secure the opening of a school by conferences with town or village councils, with clergy and private persons who might lend their assistance in the matter.

Art. 117. The programme of instruction in schools for apprentices is fixed by the Ministers of Education and Finance.

Art. 118. Where separate schools for boys and girls do not exist, and no arrangement for different hours can be made for each sex, instruction of both together is permitted, provided the pupils have not yet reached the age of 14.

Art. 119. If a school is opened for the benefit of apprentices employed at mines and factories, the proprietor is supposed to allow those persons who are in possession of certificates for only one class to attend the schools.

Art. 120. Mine and factory owners or their managers are compelled to admit industrial inspectors to examine the factories and works, and assist them in it, as well as to execute all legal instructions of officials.

Art. 121. All rules concerning the employment and instruction of apprentices by factory owners or their managers, and relating to the industrial inspections, are devised by the Minister of Finance in consultation with the Ministers of Interior and of Education, and the laws are published for general information.

SECTION III.—THE EMPLOYMENT OF PERSONS UNDER AGE AND WOMEN AT FACTORIES OR MINES.

Art. 122. Persons between 15 and 17 years of age and women cannot be employed between 9 p.m. and 5 a.m. at linen, cotton, woollen, etc., factories. This regulation can also be applied to other industrial factories, by arrangement between the Ministers of the Interior and of Finance, notification of which must be made to the owner in due course.

Art. 123. In factories and mines where 18 hours' uninterrupted work is introduced with two shifts, the time when apprentices and women are not supposed to work lies between 9 p.m. and 4 a.m.

Art. 124. In exceptional cases (for instance, after a long stoppage of work due to some accident, or when a factory is overwhelmed with orders before market days), the Office for Industrial Affairs, or where such is not represented, the Governor, has the power to allow persons of 15 to 17 years of age and women to be employed during the night at factories otherwise prohibited. It must be understood, however, that such workmen must not recommence their labour until noon on the following day.

Art. 125. The Office for Industrial Affairs and Governors have the power to allow workmen under age and women to be employed at night if the heads of their family are working at the same time with them.

Art. 126. In the Kingdom of Poland women are not permitted to work in mines, stone quarries, etc.

SECTION IV.—SPECIAL REGULATIONS RELATING TO THE MUTUAL RELATIONSHIP BETWEEN EMPLOYERS AND WORKMEN.

Art. 127. In districts where the manufacturing industries are chiefly developed (Art. 477) in factories and mines (with the exception of such belonging to the State), which are the property of private persons, they are subject to special regulations besides Arts. 86–125, concerning the mutual relationship between employers and workmen, quoted in Arts. 128–156.

Art. 128. Owners must introduce an organization order in their factories according to the rules below, and they are made responsible for any demands from their workmen which do not agree with the mentioned rules.

Art. 129. Factories not managed personally by the proprietor, or those owned by several partners or companies, must have one responsible person appointed by the owners.

Remark 1.—For large concerns having several branches, separate responsible managers may be appointed for each branch.

Remark 2.—The management of several factories by one responsible person is sanctioned in the Government of Warsaw and Petrokovsk, but not elsewhere, except by a special application to the Office for Industrial Affairs, and only in the event of these factories being near to each other.

Art. 130. The owner must give notice of the appointment of a person as responsible manager, and any change made in this position.

Art. 131. In the absence of a responsible manager or owner, a representative must be appointed, and a notice to that effect must be posted in the office.

Art. 132. The manager is held responsible for any infringement of the regulations in Arts. 86–125 and 128–152. In case of fines levied on managers not being paid within two weeks, they are collected from the owner, who must settle with the manager.

Art. 133. The factory management must keep a registry book, where all the names, ages, and residences of workmen, and the Offices which issue their passports, are entered. Passports belonging to workmen having their quarters at the factory, or living in private houses, after registration at the police-station, must be kept at the factory office.

Art. 134. Every workman, after seven days' service, must receive an account-book according to the form issued by the Governor's Office.

Remark.—Persons who are working with their children under age, or with relatives left in their care, can receive one account-book for all. (This is only by sanction of the industrial inspectors.)

Art. 135. The compulsory distribution of account-books does not apply to workmen engaged by the factory for execution of work not connected with the manufacture.

Art. 136. The account-books must not be charged for, but in case of loss or damage of same, the workman is given a new one, and charged according to the price.

Art. 137. In the account-book the following entries must be made :—

(1) Name of workman, his father's first name, and his own second name.
(2) Period of engagement, and copy of passport.
(3) Wages, calculation of such, and pay-days.
(4) Charge for quarters and baths.
(5) Other conditions the parties may desire to enter.
(6) Entries of wages received, fines levied, and reason for same.

(7) An abstract of the rules and orders in force at the factory, with a description of the rights, obligations, and responsibilities of workmen.

Remark.—For workmen engaged by contract for labour syndicates, and for handy-men, the wording of the account-books can be altered by order of the Governor's Office.

Art. 138. The account-book is given to the office for entries, and must be returned within a week. The date of handing in the account-book is noted on the receipt issued to workmen.

Remark.—In factories where workmen are provided with two books, the one kept in the office is given up in exchange for the rendered one.

Art. 139. If the conditions of the agreement made with the workmen should prove insufficient to calculate their earnings, the scale of wages posted in the office or work-shops is taken as a guide, but all such scales must bear the manager's signature.

Remark.—The rules and terms for paying handy-men, workmen on contract or labour syndicates, are defined by the Office for Industrial Affairs.

Art. 140. Workmen receiving quarters, and using the baths, tea- and dining-rooms of the factory, may be charged, but not above the sum fixed by the industrial inspectors.

Art. 141. On the property of factories there may be opened, with the sanction of the managers, supply shops to afford the workmen an opportunity of getting healthy provisions at moderate prices. The opening of other shops can be granted only by the industrial inspectors, and the prices of the goods must be fixed by the inspectors, and the list hung up in the shop.

Art. 142. The rules and orders for internal management of factories are defined by the industrial inspectors, and must contain the following stipulations:—

(1) Working hours (for grown-up workmen, and for those under age separately), the hours of commencing and ceasing work, the duration of time for rest, breakfast and dinner, and the time work is to cease before Sundays and holidays.

(2) The enumeration of holidays when no work is done.

(3) The order of time for leaving the place of work, and, for those having factory quarters, the time for quitting same.

(4) The conditions attending the use of quarters, baths, etc., belonging to the factory.

(5) The time when machines and instruments must be cleaned, and the cleaning of the factory itself, if this is part of the workman's business.

(6) The precautions to be taken for the use of machinery, and the handling of fire, etc.

Art. 143. To uphold the order of the factory, the manager has the power to fine workmen for—

(1) Negligence in performing work.

(2) Neglect of duty.

(3) Not conforming to the regulations.

No other fine may be levied, but apart from fines inflicted for negligent work by managers, the workmen can be sentenced by a court to pay damages for loss sustained by the factory.

Art. 144. A negligent work is considered to be an inferior article turned out, breaking of instruments, machinery, etc., and the fine is estimated according to the value of the article in question.

Art. 145. A neglect of duty is considered the absence of a workman during half the day, which must not be confounded with the unpunctual arrival or unauthorized quitting of the factory during working hours. Fines are inflicted for neglect of duty according to the earnings, and the number of days neglected during a month, but must not exceed a total of 6 days' wages. Those who are paid by piece-work may be fined for neglect of duty at a rate not exceeding 1 rouble a day, or 3 roubles in a month. Absence of workmen through loss of liberty, accidents, fires, floods, or death of one of their family must not be considered as neglect of duty.

Art. 146. In contravention of orders are included:—

(1) Unpunctual arrival at work, or unauthorized quitting of the factory.

(2) Failure to observe the required precautions connected with the handling of fire, especially in cases where the owner or manager deems it advisable to break the agreement by virtue of Remark 1 in Art. 5.

(3) Unclean keeping of premises.

(4) Disturbing the work by noise, quarrels, shouts, or fights.

(5) Disobedience.

(6) Arrival at work in an intoxicated condition.

(7) Arranging prohibited games (cards, etc.).

(8) Failure to observe the general factory regulations, fines for a single non-observance not to exceed 1 rouble.

Art. 147. Every fine inflicted for infringement of Arts. 143–146 must be stated in a sparate list giving the amount of the fine, and a list once confirmed by the industrial inspectors must be exposed in the factory.

Art. 148. Fines inflicted for careless work, neglect of work, or the infringement of the factory rules, cannot exceed a total sum equal to one-third of the workman's wages.

Art. 149. If the amount of the accumulated fines exceeds the limit stated in the preceding article, the manager is entitled to break the agreement.

Remark.—Workmen discharged according to Art. 149 have the right to appeal to court against the cancelling of their agreement, and if their complaint is justified, damages are granted in their favour.

Art. 150. Fines inflicted by managers must be entered in the workman's account-book not later than 3 days afterwards. The cause and the amount of the fine must be stated, and the amount may be deducted from the workman's first pay.

All fines must be entered in a special book, which is to be submitted to the industrial inspectors on demand.

Art. 151. Fines inflicted by managers cannot be appealed against, but if during an inspection the officials find, according to statements made by workmen, that the fine is illegal, the manager is held responsible for it.

Art. 152. The collected fines are entered in a special book, which is under the supervision of the manager. The fund may be employed, with the sanction of the industrial inspectors, for supplying the requirements of the workmen in accordance with the regulations issued jointly by the Ministers of Finance and Interior.

Remark.—Collected fines (Art. 152) which might remain idle through the closing of factories are added to the special reserve fund formed for assisting sick and invalided workmen.

Art. 153. Factory managers are liable—

(1) For employing workmen without account-books being given to them.

(2) And for incorrect keeping of such books, to fines from 5 to 25 roubles for each infringement. When several similar infringements are found at the same time, they are fined the total sum due for all. The fine is calculated for each case separately, according to the number of workmen without account-books, or incorrectly kept ones.

The total fine cannot exceed 500 roubles.

Art. 154. Managers are liable to fines from 25 to 100 roubles for infringement of the regulations referring to—

(1) Appointing a representative.

(2) Preserving passports and keeping a registry book for workmen.

(3) Opening factory shops and trading.

(4) Keeping books prescribed by law.

(5) Notices which must be publicly exposed.

(6) Fining workmen.

Remark.—Owners are liable to the same fine for not abiding by the laws referring to the appointment of responsible managers.

Art. 155. Managers are liable to fines of 50 to 300 roubles for the following:—

(1) Charging workmen for the use of tools and instruments which have been supplied to them free of charge, and for demanding a higher price than that allowed by law for things to be paid for.

(2) Charging interest for money advanced or security taken for their debts.

(3) Settling workmen's accounts with tickets, bread, goods, or other things in the place of money.

Art. 155. (Addition, 1895). Fines inflicted by Court or the Office for Industrial Affairs on owners or managers on account of infringements of Arts. 153–155, 1359, 1359^1, 1404^1, 1404^2, and 1404^3, of the General Code of Laws are kept for the assistance of sick and invalids.

Art. 156. The Ministers of Finance and Interior are entitled by mutual consent to extend the application of Arts. 48 to 60, and 128 to 155, on the representation of the office for industrial affairs, to large artisan workshops, also to free smaller factories, from the obligations of these articles in exceptional cases.

Instructions of the Minister of Domains *re* Oil Production.

The Control of Oil in the Caucasus (1893).

§ 1. The district engineer has control of the oil works, with all arrangements, installations of oil pipes, stations, mechanics' shops situated in the area of the oil fields, also water works which have been erected with the object of getting a supply of water for the motion of machinery.

§ 2. The district Government engineers are obliged to see that the regulations added to this paragraph below shall be observed.

§ 3. Engineers are also entrusted with the certifying of the agreements drawn up between oil producers and owners of land as explained in Art. 2531 of the mining laws.

Additional Regulations to § 2 (mentioned above).

Technical Regulations, the Keeping of which is Compulsory on Oil Producers in the Caucasus (1892–1896).

§ 1. To prevent accidents through explosions of gases on oil properties, the producers must be guided by the instructions *re* prevention of fire on Baku oil fields.

§ 2. When working in shafts, water—or oil—wells, or when cleaning ambars and reservoirs, all gases which are injurious to health when breathed, or are liable to explode, must be removed by ventilation.

§ 3. To prevent explosions during work, it is necessary to make an experiment after holidays or other interruption, to ascertain the quantity of gases before lowering any labourers for work.

Remark.—The examination of the air to ascertain the gases must be performed by means of a safety-lamp.

§ 4. It is prohibited to descend wells.

§ 5. To prevent damage to the oil strata, producers are compelled—

(*a*) to support wells with tubes, and, if it should be considered necessary by the mining controllers, to fill up the space between the tubes with some impervious substance to prevent admission of water from the upper beds.

(*b*) To fill up with clay, after removing all fossils, the lining tubes of wells out of exploitation.[*]

(*c*) On no account to permit water being poured into wells.

§ 6. Irrespective of the already sanctioned general instructions of June 8, 1889, *re* construction, fixing, and examination of boilers, the following regulations must be observed on the oil fields:—

(*a*) Maximum percentage of salt in water for feeding boilers must not exceed the limit fixed by the district Government engineer in conjunction with the technical commission.

Note.—For the Baku oil fields.

(1) Cold water supplied to boilers.

(*a*) Sea water, 2 per cent.

(*b*) Water from wells and reservoirs, 6 per cent.

(2) For hot water blown from boilers.

(*a*) Sea water, 5 per cent.

(*b*) Water from wells and reservoirs, 9 and 10 per cent.

In each boiler-house there must be aërometers and a sufficient number of glass vessels, and a book for entering the percentage of salt contained in the water used for boilers. The testing of cold water for salt must be made twice daily, and that in the boilers as frequently as is deemed advisable.

§ 7. All working parts of steam-engines and drills should be fenced round if there is any danger of an accident by carelessly coming into contact with them.

§ 8. Boring-machines must be provided with a brake.

§ 9. To prevent accidents in the event of a shaft breaking or the pulley of the drilling-machine falling, cross-beams, props, or other arrangements must be provided, depending on the construction of the drill.

§ 10. The regulations of § 7 apply also to the bailing-engines.

§ 11. Open derricks must be covered at the part where machinery is placed, the materials used for the purpose being either planks or zinc.

§ 12. The top platform of derricks, as well as the ladder, must be fenced in.

§ 13. The steps of all platforms should be connected with the main outside ladder. The ladder must be fixed at least 2 vershocks from the derrick. (A vershock is $\frac{1}{48}$ of 7 feet $= \frac{7}{48} = 0{\cdot}146$ feet.)

§ 14. Shafts, water and oil wells must be closed with timbers or fenced round when no work is being done. Boring wells must be provided with a cover during such periods.

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[*] The term "out of exploitation" is understood to mean—

1. When the exploitation has been formally stopped by an official declaration.
2. When the state of the well does not afford any possibility for further exploitation.
3. When the well has not been used for five years.

§ 15. The opening of water or oil wells in work must be fenced in with a high guard of brickwork or timber, with a cover of planks 1 vershock thick.

§ 16. Oil wells in progress must not be left without the required supervision.

§ 17. During the course of erection no strangers must be admitted into the derrick.

§ 18. The boring master must take care that no loose articles are left about the upper part of the derrick or on the platforms which could fall down and cause an accident.

§ 19. No repairs of the drill must be undertaken while it is in motion.

§ 20. Lubricating, changing of parts, and gearing and fastening of belting must only be undertaken when the drill is stopped.

§ 21. When work is being conducted in the upper part of the derrick, or when the casing is being lowered or raised, all the workmen must stand at a safe distance from the mouth of the well.

§ 22. Boring-masters and their assistants must closely observe that regulations 16–21 are strictly carried out.

Remark.—Only persons who are familiar with the technical parts of boring work are allowed to become boring-masters.

§ 23. Owners of oil properties, or their representatives, must draw up rules describing the routine and precautions to be observed in the workshops and on the property; but the rules must be revised and confirmed by the district Government engineer.

Instructions for Controlling Oil Streams (1893–1896).

§ 1. The regulations for oil streams, produced either by bailing or by fountains, are prepared with the idea of decreasing loss of oil during exploitation of wells, to protect adjacent properties from damage, and to prevent fires.

§ 2. It is the duty of the mining engineers to supervise the exploitation and regulation of the oil, and they must be guided in their duties by the general instructions, and in special cases by orders from the technical commission for guarding the oil fields.

Regulating Streams of Oil obtained by Bailing.

§ 3. A receptacle or some arrangement must be fixed over the mouth of the well into which the oil from the bailer flows.

§ 4. The raised oil should be diverted to separating tubs, and then on to ambars by pipes. Open conduits can only be fixed provisionally, connecting separating tubs with the well (the duration for such is stipulated by the district Government engineer in consultation with the technical commission for guarding the Baku oil fields), where exploitation is not in full working order, or when the well is giving oil and dirt mixed.

Remark.—The transport of oil through open conduits in cases not mentioned in § 4 can only be allowed after obtaining the sanction of the district Government engineer and the technical commission for protecting the oil fields. A special application must be made to the district Government engineer.

§ 5. The derricks must be covered with planks either from inside or outside.

§ 6. Pulleys used for bailing must be covered with a shield or other arrangement, also the wire rope which runs outside the derrick, except where the oil does not cling to the rope on account of the low level of oil and swing of the rope in the well.

A.—REGULATING STREAMS OF OIL FROM FOUNTAINS.

§ 7. The derrick must be surrounded by mounds of earth, the height and size of the embankments being made in proportion to the force of the expected fountain. If the expected fountain is situated within 5 sagenes (35 feet) of the adjacent property, a wooden barrier should be erected by the owner of the well to protect the adjoining property from being flooded with oil or covered with sand. The embankments must be so constructed that they can be easily widened in case of necessity; but any other suitable protection is permitted.

§ 8. It is compulsory to cover the derrick with planks, as well as the timbers at the top of the derrick.

§ 9. Electrical conductors must be provided with air-tight switches inside derricks where a fountain is expected, so that the light may be extinguished if a fountain occurs at night. The switches must be so situated that the current may be easily shut off.

§ 10. On the first sign of a fountain a shield must be provided, adapted to change of position, and a second one must be fixed above the first one as a reserve, in case the lower shield is destroyed. Oil producers must also have ambars of considerable size in readiness for storing the spouted oil, and make provision for removing the oil from these.

B.—DURING THE PLAYING OF A FOUNTAIN.

§ 11. When a fountain is flowing, the oil producer is compelled to appoint a well-equipped guard for superintending day and night the arrangements for collecting and storing the spouted oil, and for taking the necessary precautions to prevent destruction. The watchmen must look after boilers and pumps used for dealing with the fountain.

§ 12. The area around the spouting well, the pumps, ambars for storing the oil, etc., where work is in progress for regulating the fountain, must be well lit with electricity. Only electrical hand-lamps must be used.

§ 13. As long as the fountain is playing, there must be stationed a sufficient number of watchmen to protect those places which are exposed to any danger from fire. A notice-board must be erected, prohibiting smoking and lighting of fires.

§ 14. The electric communication with a spouting well must be cut.

INSTRUCTIONS OF THE TECHNICAL COMMISSION FOR GUARDING THE BAKU OIL FIELDS.

(Confirmed by Minister of Domains.)

§ 1. The mining department has appointed a technical commission for protecting the interests of the Baku oil fields. This commission decides all technical questions referring to the oil industry, and is under the presidency of the district Government engineer of the Second Caucasian Mining Administration.

Ten members of this commission consist of oil producers, elected by ballot at the meetings of the oil producers.

Members representing the oil industry absent in consequence of illness or other important cause, or resigning, are substituted by elder candidates, who have also been elected at the oil-producers' meeting.

Remark.—In the event of the presiding Government engineer being absent, his representative occupies the chair.

§ 2. The president has the right to invite any person who may be able to assist in the discussed question.

§ 3. The following subjects must come before the Technical Commission for guarding the wells for consideration :—

(*a*) All questions relating to the Baku oil fields which have been submitted through the president by Government officers or private individuals interested in the oil production.

(*b*) Precautions to be taken in working oil wells to prevent fires, to regulate oil fountains, and to consider any other technical question concerning the production of oil.

(*c*) Estimate of the annual expenditure for the necessary books, technical works, drawings, etc.

(*d*) The erection of fences for regulating oil fountains.

(*e*) Building of main and side roads about the oil fields.

(*f*) The preparation and presenting of annual reports of the technical commission to the Caucasian Mining Administration and to the council for oil-producers' meetings.

(*g*) Plans of technical works which are to be executed at the expense of the general oil-producers' fund, also steps to be taken for the benefit of the oil production.

§ 4. There are ordinary and special meetings of the technical commission for guarding the Baku oil fields. The ordinary meetings must take place at least once a month, and the special ones are called at the discretion of the chairman, or on demand of at least three elected members of the commission.

§ 5. The place where the meetings are to be held is chosen by the chairman.

§ 6. The minutes of the general proceedings of the technical commission are kept by the offices of the district Government engineer of the Second Caucasian District. The minutes are preserved by a specially appointed secretary, to whom also is entrusted the management of the library, technical instruments and works acquired at the wish of the commission.

§ 7. To defray the expenses of the work of the technical commission, the general oil-producers' fund is used in accordance with an estimate submitted by the technical commission to the council of the oil producers.

§ 8. All accounts referred to in § 7 are usually paid out of the oil-producers' fund ; but they must be previously certified by the chairman of the commission.

§ 9. Books, technical appliances, etc., bought at the request of the technical commission are added to the list of stock of the oil-producers' fund.

§ 10. It is the duty of the district Government engineer, in his capacity of president of the technical commission, to communicate with the respective offices on the subject of the enforcement of the resolutions passed by meetings of the commission, or to enforce them himself so far as his power allows it.

§ 11. The secretary of the technical commission is appointed at a certain remuneration stipulated in the general annual estimates, and confirmed at the meetings of the oil producers.

§ 12. The president of the commission opens and closes the meetings. He uses his power to keep the discussion within its limits, and exercises the privileges usually held by chairmen.

§ 13. The secretary reads the programme arranged for discussion at the meetings, and keeps the minutes of all the work which is under the direct supervision of the chairman.

§ 14. All questions discussed by the technical commission are decided by voting and by the majority of votes, but when there is an equal division the chairman gives his casting vote.

§ 15. Each member of the technical commission has only one vote, and he cannot represent any one who is absent. No voting in writing is permitted, but if it is the wish of the majority, decisions on important questions may be postponed until next session.

§ 16. A meeting can only take place if, besides the president and Government representatives, there are at least three members present elected by the oil producers; but in exceptional cases the president may declare a meeting open if only ordinary members of the oil producers are assembled, in which case every member receives a notification.

REGULATIONS FOR PREVENTION AND EXTINCTION OF FIRES ON THE BAKU AND TEREK OIL FIELDS.

1.—*Precautions.*

§ 1. Within the vicinity of oil wells, smoking, shooting with fire-arms, lighting of fires near derricks, ambars, fountains, and suchlike places, where there is danger of the gases taking fire, is prohibited.

Remark 1.—The boundary of oil areas is fixed by the mining administration of the Caucasian Government in correspondence with the local civil administration, assisted by representatives of the oil industry.

Remark 2.—Smoking is allowed in buildings where fire is used for working purposes, as boiler-houses, chemical laboratories, and men's quarters.

§ 2. The choice of the spot for boring an oil well is decided by the oil producer, but on the condition that boiler-chimneys, buildings where fire is used (except workmen's quarters), and lamps not lit by electricity, are situated at least 5 sagenes from the boundary. Workmen's dwellings must be built not less than 20 sagenes from oil wells, and 5 sagenes from the boundary of adjoining properties. Newly erected wells must not be placed nearer than 10 sagenes from buildings where fire is used, lamps, etc., and 5 sagenes from the boundary of adjacent properties. Workmen's barracks, blacksmiths' shops, etc., must not be nearer than 5 sagenes to the boundary, and 20 sagenes to the wells.

Remark 1.—The regulations referring to distances between buildings and wells on the plots apply equally to buildings on adjacent properties.

Remark 2.—Men's quarters and buildings where fire is used, boiler-houses, etc., may be erected near the boundary on arrival at an arrangement with the owner of the adjoining plot.

Remark 3.—The erection of boiler-houses and buildings with fire-places is prohibited in the valleys of the Grosny-Alchan-Urtoff oil fields.

§ 3. Boiler chimneys and distillery flues within oil regions must be duly cleaned from soot. Chimneys of dwelling-houses must be cleaned at least once a month, and their height must not be less than 2 sagenes from the roof of the building. Where stoves are provided with an apparatus which burns the oil completely, the height of the chimney is not subject to this regulation.

§ 4. For heating boilers and distillery retorts an apparatus of the latest invention must be used which does not discharge any smoke. Smoke from burning oil is prohibited, and must be immediately made to cease.

§ 5. For night work, or any place where light is needed, and where there is danger from explosions of gas or ignition of oil, safety electric lamps must be used, and must be fixed either on the wall or on a special post placed a fair distance from the mouth of the well. When safety-lamps are used, they may only be placed outside the derrick in a special glass case provided for them. Engine-rooms erected separately from the derrick may be lit inside with safety-lamps protected by glass cases; but, during boring such lamps may be fixed inside the derrick not more than 2 arsheens (4 feet 8 inches) from the ground.

Remark 1.—The property should be lit with oil whose flashing point is 45° centigrade.

Remark 2.—Electric light is compulsory two years after issue of these rules.

Remark 3.—Portable electric lamps provided with switches may be used.

§ 6. All lamps fixed on posts or walls, and those of a portable nature employed for lighting roads, the outsides of buildings, etc., must be fitted with a safety cover.

§ 7. Workmen handling lamps must stop work and extinguish the light if the flame begins to blaze. The lamp must be extinguished by using the same kind of hook as is used for trimming wicks, but it must never be extinguished by blowing or putting the lamp into water. When an increase in the flame is noticed, the lamp must be extinguished by a cap, or by covering with a piece of cloth. Before commencing night work, an experienced man should ascertain that there is no excess of gas by examining the lamp.

§ 8. Every property must have a special lamp store situated where there can be no danger from gases, where the lamps must be cleaned and lit by experienced and reliable men. Oil-lamps must never be cleaned or trimmed inside the derricks

§ 9. Reservoirs, ambars (open tanks), etc., where oil is stored must be constructed from a strong material when placed on the surface of the ground, and measuring vessels must be made of iron. Open ambars are allowed only provisionally, chiefly for storing oil spouted by fountains, but when the fountain ceases, the oil must be pumped from the ambars by a certain time, which is fixed by the Government engineer. If this instruction cannot be complied with owing to the enormous quantities of oil spouted, or its bad quality, the ambar must be covered with a fire-proof roof according to § 10, or the oil must be conducted away to a safe storage place. Water collected for boiler-feed purposes must not have more than 1 inch of oil on its surface.

Remark 1.—The district Government engineer may invite two mechanics from the property to confer with them as to the time to be allowed before the oil should be removed from all open ambars.

§ 10. Tanks, reservoirs, ambars, oil measuring vessels, and all other oil storages must be provided with fireproof roofs; settling-tanks may be made of wood.

§ 11. Fuel-tanks must be made of iron, and placed on masonry foundations not less than 2 sagenes from the boiler-house. This regulation applies also to fuel-tanks for men's quarters, but in this case the legal distance is half a sagene from the building.

§ 12. Near flues, stoves, etc., metal or brick boxes must be placed for the reception of sand, or the floor must be bricked, and a supply of sand kept near the spot. When householders are absent fires may not be left burning. All derricks, boiler-houses, pumping-stations, buildings or workshops where fire is used must not be left without care, night nor day.

§ 13. Oil extracted from wells should be directed to settling tanks either by pipes or closed conduits, but in no case by open chutes. Only during the spouting of a fountain may the oil be led in open channels, and these may only be used between the well and the settling tanks until regular exploitation begins.

§ 14. Derricks already in exploitation must be covered either with planks, iron, or non-inflammable material.

§. 15. The structure containing the bailing drum and the engine must be separated from the derrick by a partition, or be erected separately.

Remark.—When electric light is used these rules are not compulsory.

§ 16. Boiler-houses, blacksmiths' shops, etc., with furnaces must be constructed of bricks, stone, iron, or some non-inflammable material. Pump-stations may be built of wood, but the lighting is subject to §§ 5, 8, and 9.

§ 17. Timber dwelling-houses are not permitted.

§ 18. Where possible one boiler-house should be made to supply a number of wells on a plot by means of steam-lines, and central boiler-houses should be arranged to serve several plots. Boiler-furnaces must be placed in closed structures, but the boilers themselves may be fixed in the open air.

§ 19. When arranging for extinguishing fire with steam every available steam-pipe should be fitted with two branches, one in the derrick and one in the engine-shed, but the cocks operating these should be placed outside the derrick and engine-shed at a moderate distance. Boiler-houses and pump-stations should be provided with a similar device.

§ 20. When a well is abandoned the derrick and structures belonging to it must be removed within two years after cessation of work, and the bore-holes themselves must be securely plugged.

Remark.—All wells which have not been worked for two years prior to the publication of these regulations must be plugged, and their structures removed within one month.

§ 21. When a fountain is spouting, all fires in the furnaces of steam-boilers, blacksmiths' shops, mechanic shops, etc., near the flowing well must be closed, especially on the windward side. This regulation is compulsory not only to the owner of the fountain, but applies to the owners of adjacent properties, even if situated at a considerable distance, provided the gas and sand can reach them.

Remark.—The radius in which fires must be extinguished is decided by the Government engineer in each case singly.

§ 22. Timber stores, wooden casks, empty cases, etc., except timber necessary for repairs or immediate use, must not be stacked within 200 sagenes of the derricks, ambars, or structures with fireplaces. Chips, and other useless inflammable material must be carted away from the property.

§ 23. Within the boundary of oil areas it is prohibited—

(*a*) To light a fire in the open air.

(*b*) To burn mazoot or crude oil in lakes.

(*c*) To leave open canals, ditches, wells, etc., out of use unprotected.

§ 24. When riveting lining-tubes at night, electric light must be used.

§ 25. Refineries situated within oil areas discharging residues must be guided by the special regulations dealing with that subject.

Remark.—The regulations for preventing and extinguishing fires on oil fields apply equally to refineries.

§ 26. Grass may not be burned within oil areas, nor at a distance less than 1 verst (two-thirds of a mile) from the boundary.

§ 27. It is prohibited to live in structures belonging to derricks, or in their vicinity, or in boiler-houses or engine-rooms.

Remark.—All buildings not conforming with these restrictions must be rebuilt within six months of the issue of these rules.

§ 28. Every oil-producer is bound to have a special pump for fire purposes with all fittings, and ten water-barrels and twenty buckets.*

Remark.—Oil producers must arrange on the main steam-line a T-piece with a valve of some standard size decided for all properties by the technical commission. The spot where this attachment is fixed is shown by the district Government engineer in correspondence with the technical commission of chief of fire brigade.

§ 29. Oil properties not connected with water-lines must be provided with reservoirs, either of brick, iron, wood, or earth of a capacity of 5000 to 10,000 buckets of fresh or salt water from the wells. If the dimensions of the plot do not allow a reservoir of such capacity to be erected, oil producers may build a smaller one, but they must first obtain the consent of the mining control, and they are compelled also to come to an arrangement with neighbours who have adequate water supply.

§ 30. In the event of the water supply becoming exhausted, every property must be connected with an adjacent property or with a water lake.

§ 31. Managers, owners, and leaseholders of oil properties, village societies or single members of the latter possessing ground adjoining oil areas, must not resist the laying of water-pipes over their ground, if such are for the object of extinguishing fires.

§ 32. All buildings within the area of oil fields, except those allowed by the Minister of Domains in Art. 54 of the Oil Fields Regulations, can only be executed with the sanction of the district Government engineer, who must be guided by the rules laid down for the prevention and extinction of fires on the Baku and Terek oil fields.

Remark.—Petitions for the construction of new buildings must be accompanied by a plan of the plot showing all constructions already in existence, and also those applied for.

§ 33. The necessary information for carrying out these regulations must be given to the workmen. They must be translated into the native languages, and hung up in a prominent situation, and be read over to newly engaged workmen. The instructions for enforcing these rules must be submitted by the oil producers to the district Government engineer and local police authorities for consent.

§ 34. Managers of oil properties must name to the authorities the persons who are to be held responsible for the observance of these regulations on each property.

2. *Extinguishing Fires.*

§ 35. On the appearance of a fire on one of the oil properties a signal is immediately given by a steam whistle or syren, which is blown intermittently, and which must be followed by similar warnings from adjacent plots. Ordinary whistles must not be blown at that time.

§ 36. When the signal of a fire has been given, all properties must despatch unskilled labourers and other workmen to assist in its extinction, at the rate of one man to each well in exploitation. They must be provided with all the necessary tools which each property possesses according to instructions given.

Remark 1.—The despatch of labourers is not compulsory if the property is in the vicinity of the fire, or situated on the side to which the wind blows.

Remark 2.—Before sending labourers, the manager must explain to them their duties for extinguishing fires.

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* This rule does not apply to properties which have a separate high-pressure fire-pump, and water lines and hydrants over the properties.

Remark 3.—The number of labourers to be despatched by each property to assist in the extinction of a fire is fixed by an official of the local police force, with the assistance of two assistants elected by the responsible employees of the oil industry according to § 38. Labourers sent out to assist in checking a fire must have a metal plate pinned on their chest indicating the firm to which they belong.

Remark 4.—Managers of oil properties must notify the local mining control each time a derrick or structure belonging to them is taken down.

§ 37. Until a public fire brigade is formed, it is the duty of the local police authorities to conduct the organization work for extinguishing fires. Two assistants elected from the responsible employees of the oil industry are appointed, as well as two candidates, who replace the assistants in case of their illness or absence. The local mining control and police must be notified of the election of such persons. In districts where no police are stationed, the manager and assistants of the property where the fire originates are compelled to supervise the relief work.

Remark.—Should there be no election of assistants or representatives to assist the head of the fire brigade by an appointed date, the appointment of such persons is made by the district Government engineer in correspondence with the chief of the Baku district and the proposed persons. The appointment must be confirmed by the Caucasian Mining Administration.

§ 38. Every oil property is compelled to prepare a store, in some prominent and convenient spot near the centre of the plot where it is less exposed to danger, to which a signboard is attached containing the words, "Store for Fire Instruments," and followed by the name of the firm. There should be three sets of keys for this store, one to remain with the manager, one with the watchman, and one with the head employee of the property.

Remark 1.—Small companies who possess ground of limited area may unite and arrange amongst themselves for a common store of fire appliances, but they must previously advise the district Government engineer.

Remark 2.—The list of fire-extinguishing appliances is made by the head of the local police, assisted by the two employees of the oil industry, if a permanent fire brigade has not been formed. A copy of such list must be forwarded to the local mining administration.

§ 39. Managers of properties are compelled to keep all roads and bridges on their property, whether they are for their own or general use, in a good state of repair. They must be well lighted, and the precautions mentioned in §§ 2, 5, 7, 8, and 9 must be observed.

§ 40. During a fire all wells in exploitation within a radius of 150 sagenes (1050 feet) must be immediately stopped. In the direction in which the wind is blowing all wells must be stopped where sparks can reach them.

§ 41. The local mining administration and the police authorities must be at once informed of an outbreak of fire by the property managers, either by telephone, telegraph, or where such are not connected, by some other means.

§ 42. The time allowed for the fulfilment of these instructions is, except in cases specially mentioned in the rules, fixed by the Mining Department of the Caucasus.

3. *Enforcement of Regulations.*

§ 43. The local mining administration must enforce these regulations, and in cases of non-compliance take legal proceedings to have the rules carried out. The summons must be issued in case of necessity with the aid of the local police, and the guilty parties brought before the police court and charged.

RULES FOR OIL-PRODUCERS' MEETINGS.

1. *Purpose, Time, and Place of Meetings.*

§ 1. With the consent of the Minister of Domains, meetings of the oil producers are arranged. There are ordinary meetings once a year, not later than November, and special meetings, which are called whenever they are deemed urgent.

The work consists in—

(*a*) Making statistics of the output of crude oil, and the production of the refineries, and considering the transport facilities of the Trans-Caucasian Railway, and the working and capacity of pump-stations.

(*b*) Discussing economical and administrative questions referred to meetings.

(*c*) Considering the requirements of the oil industry, and discussing any subject recommended for consideration by the Minister of Domains.

(*d*) Deciding the rate of tax to be collected from the producers to defray the expenses of meetings dealing with the needs of the oil industry.

(*e*) Arranging and altering, in accordance with the railway administration and steamship lines, rules regarding the transport of oil products.

Remark.—Such rules must subsequently be submitted to the Minister of Communications for consent.

§ 2. Time, place, etc., are fixed by the Minister of Domains in conjunction with the head of the Caucasian Civil Service Department.

§ 3. The advisory committee of the meetings makes representations to all respective Government offices on questions referring to the requirements and the administration of the oil industry in the Caucasus.

2. *Arrangement of Meetings.*

§ 4. Meetings take place under the presidency of a person specially selected by the Minister of Domains each time.

§ 5. Not later than three weeks prior to the date of the meetings, the president must publish in the local and the St. Petersburg newspapers a notice stating the date, place, and particulars of the coming meeting.*

§ 6. The following persons take part in the session of meetings:—

(1) Officials appointed by the ministers.

(2) Oil producers or their managers.

(3) Representatives of railway and steamship companies connected with Baku.

§ 7. The chairman has also the power of admitting to the meetings, and allowing to vote, persons associated with science, technical enterprises, commercial syndicates, Government town and village offices; in fact, all people interested in the welfare of the oil industry.

3. *Method of Conducting Meetings.*

§ 8. When the session is opened the members elect a secretary whose duty it is to keep a journal of the proceedings.

§ 9. Each member has the right of participating in the debates, but he may also hand in his opinion in writing on the subject under consideration. The paper is read during the session, and printed later with the general reports of the meetings.

§ 10. At the opening of the meeting the following reports are submitted:—

(*a*) Of members appointed by the oil-producers' meetings to act as a railway committee to arrange the distribution of tank-wagons on the Trans-Caucasian Railway.

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* This rule does not apply to special meetings.

(*b*) Of the committee for revising the expenditure and returns of the oil-producers' association.

(*c*) Of the advisory committee of the oil-producers' association to decide upon the enforcement of certain resolutions passed at the previous meetings, and upon inquiries received since the termination of the last meeting.

(*d*) Of the Baku technical commission.

(*e*) Of the technical commission for protecting the Baku oil fields.

(*f*) Of the representatives of the oil industry in the mining administration of the Caucasus.

(*g*) And of all other commissions appointed at the meeting of the oil producers. Other proceedings depend upon the resolutions of the meeting and the chairman.

§ 11. A record is kept of all decisions. They must be read before the meeting when adopted, and signed by the chairman, secretary, and at least three members. The general report on the decisions and proceedings of the debates, etc., is printed and submitted to the Minister of Domains.

§ 12. If it is deemed necessary, the meetings may appoint a special commission for a closer study of special subjects.

§ 13. If divergent views are held, or a protest of several members is lodged during the discussion, the point must be decided by open voting to arrive at a decision. All members elected according to § 6 may participate in the voting.

§ 14. On the request of at least ten members, open voting may be superseded by closed voting. (On paper.)

§ 15. In the debate on a subject connected with expenditure, only persons mentioned in § 32 have the right to vote.

4. *The Officials of the Meetings. Their Powers and Obligations.*

§ 16. The following officials are appointed to assist in the work of the oil-producers' meetings—

(*a*) Chairman.

(*b*) Five members of the advisory committee, and at least three candidates.

(*c*) Members of the Baku technical society.

(*d*) Members of the revising committee.

(*e*) Members of the technical commission for protecting the Baku oil fields.

(*f*) The representatives of the oil industry with the Mining Administration of the Caucasus.

(*g*) And, by a mutual arrangement between the Ministers of Domains and Communications, also members of the Trans-Caucasian Railway committee for distributing oil wagons amongst the producers.

§ 17. The members of the railway committee act according to instructions given to them by the Minister of Communications. They must hand in a report of their work to the advisory committee of the oil-producers' meetings, and distinctly state the number of wagons, tanks, etc., distributed amongst producers for transporting oil; also the description of loads, and the point of destination along the Trans-Caucasian Railway.

§ 18. The staff of the revising committee, besides persons elected at the meetings, consists of any officials specially appointed by the Minister of Domains.

§ 19. The duty of the revising committee is to check the expenditure and returns, and it is expected to forward a report at the first session of the oil-producers' meetings.

Remark.—It is also the duty of this committee to check beforehand the estimates

for expenditure, and returns for the coming year, submitted to the meeting by the advisory committee.

§ 20. The advisory committee is composed of the chairman and not more than five members. If one of the members resigns, his place is filled by a candidate, who is elected by the majority of votes of those present. In the absence of the chairman, the meeting is presided over by one of the members of the advisory committee, who is elected from among themselves.

Remark.—One member of the advisory committee acts as treasurer.

§ 21. The programme of work which the advisory committee suggests carrying out is recommended to the meeting for adoption.

§ 22. The presence of at least three members at the conference is necessary to arrive at a decision.

The majority of votes carries a proposition.

Remark.—When equal numbers of votes are given, the chairman decides by a casting vote.

§ 23. The advisory committee is entitled to grant powers of attorney to other persons. Such individuals receive their instructions from the committee, by which they must be guided, and they must submit a report on their work, and forward in due course copies of petitions, declarations, also original replies received by them.

§ 24. The advisory committee's duties consist in—

(*a*) Keeping in touch with the Minister of Domains, and representing, as far as its powers allow it, the interests of the oil industry at various railway and Government offices, and in private enterprises and public companies wherever its assistance to the oil industry might be deemed of value.

Remark.—Communications with the Minister of Domains take their ordinary course through the Caucasian Mining Administration, and only in special cases should direct correspondence with the Minister take place, when a notification to that effect must be sent to the Mining Administration.

It is also the duty of the advisory committee to inform, in the same way, the Minister of Domains, about any requests made on behalf of the oil industry to other Government offices.

(*b*) Executing, with the authority of the meeting, the preliminary work of subjects awaiting decision; also, on the request of Government offices, to furnish them with information and particulars of questions discussed during the year.

(*c*) Preparing, with the assistance of the district Government engineer, the complete statistics of the total production of oil properties, pump-stations, and refineries, and preparing lists of members who are to take part in the next session with particulars of the last few years' production, and issuing tickets to such members entitling them to vote.

(*d*) Submitting a programme of work for the next meetings, a copy having been previously sent to the Minister of Domains for confirmation.

Remark.—Oil producers desirous of opening a discussion on a certain subject, must send to the advisory committee a note giving particulars of the subject in question. This must be added to the programme if at least five members have attached their signature.

(*e*) Calling a special meeting when such a step is deemed necessary.

(*f*) Placing before the next meeting an account of their work. The financial report must, however, be submitted to the advisory committee for verification.

(*g*) Rectifying the stenographic report of the session. Such report must be sent to all the members of the meetings, and to various Government offices and officials.

(*h*) Raising a fund to be used for defraying expenses of meetings and the advisory committee.

(*i*) Engaging clerks and other employees.

(*j*) Receiving sums for the requirements of the oil industry, and disbursing money according to the confirmed estimates.

Remark.—Money received by the advisory committee must be deposited with the local branch of the State Bank, and may be withdrawn by cheques signed by the chairman and treasurer.

(*k*) Collecting and printing periodically (if possible, weekly) information on the output of crude oil, the quantities conveyed by pumping stations, quantity of refined products, and other statistics referring to the progress of the export trade and the market.

§ 25. Any complaint about the advisory committee or its members must be placed before the committee, which puts it before the meeting with a comment attached.

§ 26. The advisory committee has a separate office of its own, engages clerks, and arranges the work independently.

§ 27. The rate of remuneration, office expenses, etc., are fixed at the meetings.

5. *The Election of Officials at the Meetings.*

§ 28. Every person entitled to a vote according to § 32, can be elected as an official to the meetings.

Remark.—Members of the technical committee, and the technical commission for preservation of the oil fields, may be elected, although not entitled to vote at the oil producers' meetings.

§ 29. All officials are elected for a period ending with the next session. The chairman and the members of the advisory committee are elected for three years. Retiring officials may be re-elected for the same or some other position.

Remark.—One year after the enforcement of these regulations, two members of the advisory committee and one candidate must retire by drawing lots. Every second year two members and one candidate, and every third year one member and one candidate, must retire.

§ 30. If the chairman resigns his position before the election time, his position is taken until the next meeting by one of the members of the advisory committee chosen by his colleagues.

If, however, a member of the advisory committee resigns, one of the candidates elected by the majority is appointed in his place until the next meeting.

§ 31. The election of all officials is by secret ballot, the majority of votes deciding.

§ 32. Only persons who are actually engaged in the oil industry, either extracting or refining oil on their own or leased ground, but paying the royalty per pood for the requirements of the oil trade, are entitled to vote either personally or by a representative who is authorized by a power of attorney.

Remark.—Owners who have leased their properties to other persons lose their vote, which is transferred to the leaseholders.

§ 33. Oil producers, refiners, etc., are classified into two groups—large and small companies. The votes are divided as follows: In the first group, one vote is allowed for each 1,000,000 poods of crude oil, and 400,000 poods of kerosene or lubricating oil, or 4,000,000 poods of oil conveyed by pipe-line. In the second group, one vote is allowed for each 500,000 poods of crude oil, and 200,000 poods of kerosene or lubricating oil, or 2,000,000 poods of oil conveyed by pipe-line.

§ 34. The votes are reckoned for each branch of the industry separately; thus, one person may vote for each branch separately.

§ 35. Oil properties extracting, refining, or pumping quantities less than indicated above, must amalgamate to obtain a vote, which must be transferred to one of them elected as a representative.

§ 36. Every ordinary member may act for an absent member, but only for one.

Remark.—If the vote is not handed in personally, the signature of a power of attorney must be certified by two members, or by a notary. The chairman must control the votes, which is generally done before the opening of the meeting.

6. *Finance.*

§ 37. To defray the expenses of meetings, officials' salaries, etc., a special pood royalty is levied on the oil extracted, refined, or conveyed by rail or pipe-lines; but the rate must not exceed the limit fixed by Art. 555 of the Mining Laws.

LAWS AND INSTRUCTIONS ISSUED BY THE GOVERNMENT IN 1900–1901.

Ratification of provisional regulation *re* leasing of Government ground, supposed to be oil-bearing, for exploration and exploitation, without public auction. On May 14, 1900, the Committee of Ministers sanctioned the following provisional rules and regulations:—

I.—Provisionally the Minister of Domains has the right to grant leases for Government land supposed to be oil-bearing, except that which is actually proved to be oil-bearing, on the Apsheron Peninsula and other districts; also for areas which have not yet been declared oil-bearing, but which, nevertheless, expose a show of oil.

The basis on which Government ground is leased is as follows:—

1. The Minister of Domains, in conjunction with the Civil Service Department in the Caucasus, and with the assistance of a commission specially appointed by him, gives a final decision on plots in certain districts suitable for exploration. The Minister of Finance appoints a representative on this commission as well as the Government control, and it is mutually decided what boring work must be undertaken by the lessee of the plot.

2. The leasing of such areas is made known in due course by a notice inserted in the newspapers not less than twice annually. The size of the ground must not exceed the limit of exploration plots defined by law.

3. Persons desiring to lease oil-bearing land must send in an application to the Mining Administration.

The Minister of Domains has the power of refusing a lease to any person he deems unreliable, and who would not conduct correctly the exploration work.

4. As a security for the proper fulfilment of the regulations referring to the boring of wells, persons wishing to obtain a plot must deposit 5000 roubles with the application, and after receipt of the lease the security must be increased by a further sum of 5000 roubles.

Each case is separately considered according to the number of applicants, and the Minister of Domains has the power to increase the amount of security to 50,000 roubles. Should there be several applicants for the ground on these terms, lots are drawn.

The person who receives the plot must deposit half the security at once, and the balance when possession is handed over to him.

5. Twelve months after the lease has been granted, the lessee is bound to proceed with regular boring operations, and within the first three years one or several wells must be completed at the depth stipulated in the agreement.

6. If the exploration proves successful, the lessee has the right to apply for 10 dessiatines (27 acres) within the area of the explored territory for exploitation, for a period of 24 years. A ground-tax must be paid according to Art. 576 of the Mining Laws.

7. Areas adjoining the boundary of already explored ground can only be leased by public auction.

The Minister of Domains has authority to alter or complete the provisional regulations.

STIPULATIONS FOR LEASING GOVERNMENT LAND FOR EXPLORATION AND EXPLOITATION WITHOUT PUBLIC AUCTION ACCORDING TO PROVISIONAL REGULATIONS SANCTIONED AND ISSUED ON MAY 14, 1900.

§ 1. The following areas situated in the Baku Government and district can be obtained on lease by virtue of the regulations:—

1. In the vicinity of the mud volcano "Pilpila," 1 verst to the north-west of the station Chvalenski, on the Trans-Caucasian Railway.
2. Around the mountain "Achtarma," about 1 verst away.
3. Land near "Pilpila," 1 verst west of mountain "Achtarma."
4. Close to the mountain "Otman-Basi-Dag," roughly 7 versts west of Chvalensk, station on the Trans-Caucasian Railway.
5. Ground around the hill "Bos-Dag" (mud volcano), about 6 versts west of the village Gesdek.
6. Land to the south-east of the Romany Lake, near the boundary of the Romany and Saboontchy districts, except ground already chosen for public auction.
7. Saline "Bool-Booli," in the district near the village Chilla (Amirdyan) and Bool-Booli.
8. Saline bed to the north-west of the village Surakhany, to the south of Government group XVIII. and the space around the fire-mountain "Atashka," in the district of the village Chilla.
9. Site of the saline "Karachkoor," about 1 verst north-east of the Surakhany factory.
10. Land near the hill Zig-dag (Sukhan-Bakhchi), close to the Sekhanski salt-lake and Cape Sultan, adjoining the village Zikh.
11. District of the village, to the south-west of the salt-lake bed.
12. Saline bed west of the village Diga, near salt-lake bed Kir-Maku.
13. Saline bed Beook-Shor, on the north-west side in the district of the villages Balakhani and Diga.
14. Saline bed to the north-west side of the village Fatmai, particularly the eastern bank, and space between east and west salt-lake beds.
15. District of the village Nookhani, more particularly the north-western shore of Masasir Lake.
16. Beepeli Hill (and its continuation hill Sian-dag), with its gas exudations in region of the villages Nobkhami and Gorodil.
17. Around the village of Masasir, south of the mud volcano "Keireki," saline "Keirekishor," and the elevation "Kogan-dag" (Kegal-dag?), 2 versts south of Masasiri Lake.

18. Ground adjoining the salt lake "At-Batan" (Djuran-Batan) and the mud volcano in the district of the village Sarai.

19. The eastern part of the region of the village Khoordalan, joining the hill Sigil-dag, and also a portion of the same area south of the railway line.

20. Mud hill "Bos-Dag," 2 versts west of the village Gekmali, with the mud volcano in the district.

21. Puta Bay, 8 miles to the south-west of Baku.

22. Land to the east of the village Binagadi.

23. The village Keotal.

24. The village Agdja-Mamed (or Gadji-Mamed).

Remark.—Plans of the areas indicated above may be seen at the office of the Mining Department in St. Petersburg, at the office of the Mining Administration of the Caucasus at Tiflis, or at the office of the district Government engineer for the II. Caucasian District in Baku.

§ 2. Persons of all classes possessing civil rights, but with the restrictions noted in Art. 547 of the Mining Laws, and the Remark, wishing to lease one or several plots enumerated above, must make a written application to the Mining Department with the necessary revenue stamps attached, and present it not later than September 1 of the current year.

§ 3. The applicant must deposit, at the time of making his petition, with the Mining Department or with the next Government Treasury Office in favour of the first-mentioned department, a sum of 5000 roubles for each plot desired. One month after being notified that his application for one or several plots has been granted, he must pay a further sum of 5000 roubles a plot. The full deposit for each plot is, therefore, 10,000 roubles, which is kept as security for the fulfilment by the lessee of the obligations with reference to boring wells, etc.

§ 4. After having paid the security in cash, the lessee must comply with Art. 35 of the code relating to land taxes. The Minister of Domains has the right to refuse the grant of a plot to an applicant who he does not consider will satisfactorily fulfil the conditions of the lease.

§ 5. The Minister of Domains may increase the amount of security up to 50,000 roubles in some circumstances. If there are several persons desiring to lease the same plot at an equal security, lots are drawn to decide. The applicant to whom the plot has been leased must pay the balance before taking possession of the ground (§ 3).

§ 6. Persons who have received the right for prospecting or exploiting oil on one of these plots (§ 1) must notify the plot within 2 months from the time permission has been obtained (the plot is left to his choice), which must correspond in size and form to Art. 560 of the Mining Laws. The boundaries of two adjacent plots must not overlap, and in case of a dispute between persons who have exploration or exploitation rights in the same area, the Government engineer of the II. Caucasian Mining District settles the dispute by defining the boundary of each lessee, and forwards his decision through the Caucasian Mining Administration to the Mining Department for ratification.

§ 7. After choosing a plot the explorers send a declaration to the Government engineer of the II. Caucasian District in Baku, which is generally certified by him. Within 1 month of obtaining the right to explore (the time to be counted from the day of handing in the declaration), a form provided with revenue stamps to the value of 1 rouble for each plot must be presented to the district Government engineer.

§ 8. Persons failing to describe in due course their choice of a plot, or to appear at the date fixed for receiving the lease, lose their security (§ 3 and 5) and their claim to the plot.

§ 9. The district Government engineer must notify immediately to the Office of Domains in Baku or the Province of Terek the granting of a lease. The Office of Domains must within 6 months of the granting of a lease deliver to the lessee the possession of the plot. A document is drawn up, signed by the official of the Office of Domains, the lessee or his representative, and an official of the Mining Control who is present. There must be a plan of the leased plot attached to the deeds of possession, and these are left with the local Office of Domains, and copies of them sent to the Caucasian Mining Administration.

Remark 1.—All expenses connected with the despatch of officials to conclude this agreement are charged to the lessee.

Remark 2.—The lessee may commence work immediately after the signing of the agreement, not waiting for the formal deeds of possession; but if it should ultimately be found that he overstepped the boundary and conducted operations on land belonging to other persons, he will have to vacate such ground, and will have no claim for damages against the State or his neighbours.

§ 10. Twelve months after the completion of the agreement the lessee must commence regular boring work of at least one well, and within three years must reach a depth of not less than 200 sagenes. If during this period oil is discovered at a smaller depth, the lessee may commence exploitation. If, in the first six months, the well gives less than 10,000 poods a month, and afterwards this output decreases, the Mining Control can compel the lessee to continue boring to a depth of 200 sagenes. The same regulations with regard to regular exploitation and deepening of wells on leased Government ground are to be applied in cases when, after the first flow of oil, an oil stratum is found in the lower part of the single compulsory well, where a trial bailing and regular exploitation could be started.

§ 11. The length of the trial bailing and preliminary work necessary for the exploitation of the compulsory well is not included in the three years' period during which the lessee must reach a depth of 200 sagenes. A special entry is made by the Mining Control of the Caucasian Mining Administration. The time during which no work can be conducted owing to an accident, such as damage to casing and breakage of boring instruments, the fishing for and repairing of which would occupy a considerable time, is excluded from the defined three years. Stoppage of regular work is also recorded by the official mentioned in this paragraph.

§ 12. If the trial bailing or exploitation demonstrates that there is no chance of deepening the well to 200 sagenes, the lessee must commence boring a new well to the prescribed depth, the time of completion being reckoned independently of the three years (§ 9).

§ 13. If the lessee does not comply with the regulations in §§ 10 and 12, the Mining Administration may issue an order and cause the plot with all erections to be taken from the lessee and handed over to the Crown, no compensation being given to the holder. The security is forfeited as damages and added to the State revenue, and the agreement is cancelled.

§ 14. During exploration the lessee must collect samples of all the strata passed, and keep a journal according to the form prescribed. A copy of the journal must be forwarded to the district Government engineer. If an examination of boring work is instituted by the Mining Control surveyors or geologists of the Caucasian Mining Administration, the lessee must supply them with every facility, show them samples of every stratum passed which could give the officials an idea of the formation explored. In case of necessity, the Mining Administration may compel lessees to keep a detailed account in the boring journals of geological strata met with on their land.

§ 15. Lessees of Government land may erect all structures for boring and exploitation work, but must comply with all instructions and regulations concerning the production of oil, and mining operations so far as relates to the oil industry.

§ 16. Lessees who have within three years reached 200 sagenes and found no oil or only such in unpayable quantities, may, if they are so disposed, continue to bore deeper. They must, however, notify the Caucasian Mining Administration of their desire, and specify the depth to which they intend to bore. This office, with the sanction of the Minister of Domains, fixes a new term for the completion of boring work, taking into consideration the depth to which the lessee proposes to bore, if the unexpired portion of the three years is insufficient to complete the work. All regulations mentioned in §§ 10 and 11 refer to the new term named.

§ 17. Lessees having complied with all instructions and regulations wishing to cease explorations must give six months' notice to the Caucasian Mining Administration. During this time the Crown takes over the plot, and the lessee may remove all erections, etc., with the exception of the last column of casing in the wells. All property left by the lessee on the plot after the expiration of six months, including the casing in the wells, becomes the property of the Government without any compensation to the owner.

§ 18. After the plot has been returned to the Crown, the lessee receives his security back.

§ 19. If boring operations prove successful, the explorer may apply for a plot in the prospected area, the size of which must not exceed 10 dessiatines. A petition must be forwarded to the Caucasian Mining Administration, together with a plan of the explored ground signed by the surveyor of the same administration, and stating that the plot shown on the plan does not exceed 10 dessiatines. In addition to the petition two separate plans and two journals of the explored ground must be sent certified as correct by the surveyor of the Caucasian Mining Administration. The boundaries of the property must be clearly defined, and the exact length and breadth must be stated.

§ 20. On receipt of an application, the Caucasian Mining Administration issues an order to prepare a new lease of 24 years for the explorer, and fixes a land-tax according to Art. 576 of the Mining Laws. The deeds of possession for 10 dessiatines are then deposited with the lessee by an official of the Mining Administration. The lessee must pay all expenses connected with the transfer.

§ 21. As a security for the regular payment of rent, as stipulated in the agreement, a sum is detained from the deposit left with the Mining Administration for the exploration, equivalent to half the annual rental determined for exploitation, but the balance of the original deposit is returned to the lessee. In cases where the deposit for exploration does not amount to the sum needed for exploitation, the lessee must pay the additional sum.

§ 22. The conditions for the payment of rent and the consequences of irregular settlement are the same as stated in Arts. 578–582 of the Mining Laws, and the means of recovering outstanding rents and fines are the same as stated in Art. 582. The amount due is first deducted from the security (§ 21), but if this is not sufficient an interdict is put on the other property of the lessee.

Remark.—Oil producers paying the rent within two weeks of the date it is due to the State Treasury Office (according to Art. 70 of the Land Taxes) escape the fine levied according to Art. 578 of the Mining Laws.

§ 23. The transfer of properties under exploration or exploitation from one person to another, as well as the entering into partnership with other persons, is only allowed with the full sanction of the Minister of Domains. An application must be made through the Mining Department of the Caucasian Mining Administration signed by the lessee and the persons acquiring the ground, or the new partners, as the case may be. Such transfers are only made legal when a note is attached by the Mining Administration on the original agreement.

Remark.—The new signatures must be certified by a notary.

§ 24. The transfer of the whole or a portion of a Government-leased plot can only take place after the agreement between the Government and the lessee is finally concluded.

§ 25. The original agreement for exploration and exploitation of the plot (10 dessiatines) with all other documents, viz., the deeds of possession, etc., must be deposited with the office of the Caucasian Mining Administration, and copies of them are delivered to the lessee after the latter has paid the amount necessary to buy the revenue stamps for affixing to the documents.

Alterations of §§ 11, 12, 23, and 31 *re* private instructions for enforcing the regulations referring to private mining enterprises:—

On August 5, 1900, the Minister of Domains ratified the alterations to §§ 11, 12, 23, and 31, *re* private mining exploitation of Government ground (Arts. 255–333 of Mining Laws).

§ 11. (Referring to Arts. 17, 18, 19, 273–275 of Mining Laws.)

Application for licences for exploration must be made in writing. The full name and address of the applicant, or the person authorized to receive the prospecting licence, must be stated. Any change of address must be communicated to the local Office of Domains. When an application is received, the Office of Domains must make investigations and ascertain whether the petition refers to lands which are not thrown open for exploration purposes according to Arts. 2–5 (Arts. 256–259 of the Mining Laws, and § 2 of these laws), or to grounds which are subject to special regulations. If the land is found to belong to the first division the application is refused, and if to the second class the special laws dealing with the ground are distinctly notified on the licence, and it is explained—

(1) That the applicant must deposit with the Government Treasury to the account of the local Office of Domains a security, the amount of which is fixed by the Minister of Domains on the advice of the latter office.

(2) That exploration may be commenced after the deposit has been accepted.

(3) That delay in depositing the security which would hinder the commencement of exploration, the date of which is legally fixed at a stated period (Art. 283 of the Mining Laws), is not justified as an excuse for retarding the work, and will not protect lessees against the consequences described in Art. 288 of the Mining Laws. If the information to hand leaves some doubt as to whether the plot applied for is situated amongst the lands enumerated above, an examination is made on the spot prior to the issue of the prospecting licence.

If the peg on the plot applied for (Art. 17 with Remark, also Art. 273 with Remark of the Mining Laws) should be found in such close proximity to plots leased to others that there is no opportunity of granting the full size without overstepping the boundary of neighbours (*i.e.*, 1 verst north, south, east, and west of peg), this would constitute an objection to the granting of a prospecting licence, but a remark is made on the deeds indicating that only a portion of a full-sized plot has been allotted extending as far as the boundary of adjacent properties. A detailed description of the adjacent plots must be made in the licence. When a prospecting licence is issued an observation is made of the position of the peg on the map (see § 3) with the date when the licence was granted. This date is usually abbreviated; for instance, 10^5/1888 represents the 10th of May, 1888.

§ 12. (Addition to Art. 20 and Art. 276 of Mining Laws.) When receiving an application for a prospecting licence, the local Office of Domains writes on the document not only the date, but also the hour when it arrived. Applications received by the same mail are considered as equal. The drawing of lots, in cases where such a proceeding is deemed expedient, takes place in the presence of the applicants or their representatives. In the absence of one applicant, notwithstanding the service of due notice to both parties, the drawing proceeds. If both persons fail to appear a new time is fixed, but if after the expiration of one month from the newly appointed time neither party calls, their applications are cancelled.

Not later than three days after the signing of the licence the document is delivered to the applicant or his representative. In case of their absence the licence is forwarded to the police-station for delivery to the correct address. If the police are unable to find the applicant the licence must be returned to the local Office of Domains, with a remark to that effect, upon which the Office publishes in the newspapers an intimation that the licence awaits the applicant, and that unless claimed within three months he will lose his right to it.

If the police authorities return the licence with a note that the applicant or his representative refused to accept it, a term of one month is allowed, during which time an explanation from the applicant must be forthcoming. If such an explanation is found to be justified a new prospecting licence is granted, dating from the time of issue; but if the new licence will also not be accepted by the applicant it is equivalent to renouncing all his rights to exploration.

§ 23. (Addition to Arts. 33–36, 291–294 of Mining Laws.) On the application form for a plot reserved for exploitation the full name and address of the producer or his representative must be given, and any change of address must be duly notified. Every notice sent by the Mining Administration or Control to the producer goes through the medium of the police authorities, and is accepted by him or his representative. If not delivered, the notice must be immediately returned by the police to the Mining Administration, with a note explaining the reason of non-delivery.

This despatch is considered equal to a personal delivery to the producer.

Plots applied for must not exceed the stipulated size granted for prospecting. They may, however, be situated differently, and be of various sizes, but each should be larger than 1 square verst, and the breadth must equal at least $\frac{1}{3}$ of the length, provided there are no other obstacles through the position of the land.

§ 31. (Additions to Arts. 52 and 311 of the Mining Laws.) Not later than 3 years after handing over possession of a plot, the Administration must fix a limit for the annual production of oil on Government properties. This limit is fixed on the representation of the Mining Control, which previously makes an inspection of the works. The producer is generally advised of the day when such an inspection will take place (§ 23). The absence of the producer will not prevent the officials
lling their duty. The limit fixed is communicated to the Mining Control by
nistration, which must notify the producer and enforce all instructions

connected with it. Should the address of the producer not be known to the officials, a notice is published in the newspapers.

Any complaints against these regulations must be handed to the Minister of Domains at the times noted in Art. 71 of these regulations (Art. 330 of Mining Laws). After the expiration of 20 years the Mining Administration presents to the Minister of Domains its views on the fixing of a new minimum oil-production or to leave in force the same figure for another 20 years.

APPENDIX C.

USEFUL FIGURES AND DATA.

RUSSIAN WEIGHTS AND MEASURES.

Money.

100 copecks = 1 rouble. (1 copeck = approximately 1 farthing.)
9·45 roubles = £1 sterling.

Long Measure.

1 vershok = 1·75 inches.
16 ,, = 1 arsheen = 2 feet 4 inches.
48 ,, = 3 ,, = 1 sagene = 1 fathom = 7 feet.
2400 ,, = 1500 ,, = 500 ,, = 1 verst = 0·663 miles (English).

Square Measure.

256 sq. vershoks = 1 sq. foot.
49 sq. feet = 1 sq. sagene.
117,600 ,, = 2400 ,, = 1 dessiatine = 2·6997 acres.
250,000 ,, = 1 sq. verst.

Liquid Measure.

(The standard measure in general use is the vedro.)

1 vedro = 2·7069 gallons = 27·069 lbs. of water.

Weight.

96 zolotnik = 1 foont.
3840 ,, = 40 ,, = 1 pood = 36·1141 lbs.
62·2 ,, = 1 ton.

THERMOMETERS.

To convert Fahrenheit to Centigrade $C.^\circ = \frac{5}{9}(F.^\circ - 32^\circ)$.
" " Réaumur $R.^\circ = \frac{4}{9}(F.^\circ - 32^\circ)$.
" Centigrade to Fahrenheit $F.^\circ = \frac{9}{5}C.^\circ + 32$.
" " Réaumur $R.^\circ = \frac{4}{5}C.^\circ$
" Réaumur to Fahrenheit $F.^\circ = \frac{9}{4}R.^\circ + 32$.
" " Centigrade $C.^\circ = \frac{5}{4}R.^\circ$

ATMOSPHERE.

The atmosphere contains by weight—

Oxygen . . .	20·84 per cent.
Nitrogen . . .	79·16 "

The atmosphere contains by volume—

Oxygen . . .	23·15 per cent.
Nitrogen . . .	76·85 "

Pressure of atmosphere = 14·7 lbs. per sq. inch.
" " " will support 33·8 feet of water.
" " " " " 38·0 " crude oil.
1 lb. air = 12·385 cubic feet at 32° F.
1 lb. air = 13·14 cubic feet at 62° F.

Air required for combustion of 1 lb. of coal = 11 to 12 lbs.
" " " " petroleum = 14 to 15 lbs.

WATER.

1 cubic foot water = 62·425 lbs. = approximately 1000 ozs.
" " = 0·557 cwt.
" " = 1·7826 pood.
" sea water = 64·11 lbs. (1·027 times fresh water).
" Baku well water = 63 to 75 lbs.
" Caspian water = 63·25 lbs.
1 gallon water = 10 lbs.
" = 0·16 cubic foot.
1 ton water = 35·29 cubic feet.
" = 224 gallons.

Latent heat of water = 142 B.T.U.

Ordinary sea water contains 3·5 per cent. of salts in solution.
Caspian Sea water " 2·0 " " " "

STEAM.

The following table furnishes all the information needed for common calculations of steam :—

PROPERTIES OF SATURATED STEAM.

Pressure in lbs. per sq. inch above vacuum.	Temperature in degrees Fahr.	Total heat units from water at 32°.	Latent heat.	Volume of 1 lb. in cubic feet.
1	101·99	1113·1	1043·0	329·3
2	126·27	1120·5	1026·1	171·7
3	141·62	1125·1	1015·3	117·3
4	153·09	1128·6	1007·2	89·51
5	162·34	1131·5	1000·8	72·59
6	170·14	1133·8	995·2	61·16
7	176·90	1135·9	990·5	52·92
8	182·92	1137·7	986·2	46·68
9	188·33	1139·4	982·5	41·79
10	193 25	1140·9	979·0	37·85
14·72	212·00	1146·6	966·6	26·33
15	213·03	1146·9	965·1	25·86
20	227·95	1151·5	954·6	19·74
25	240·04	1155·1	946·0	16·01
30	250·27	1158 3	938·9	13·49
35	259·19	1161·0	932·6	11·67
40	267·13	1163·4	927·0	10·28
45	274·29	1165·6	922·0	9·217
50	280·85	1167·6	917·4	8·347
55	286·89	1169 4	913·1	7·631
60	292·51	1171·2	909·3	7·032
65	297·77	1172·7	905 5	6·525
70	302·71	1174·3	902·1	6·086
75	307·38	1175·7	898·8	5·703
80	311·80	1177·0	895·6	5·368
85	316·02	1178·3	892·5	5·071
90	320·04	1179·6	889·6	4·806
95	323·89	1180·7	886·7	4·568
100	327·58	1181·9	884·0	4·353

PETROLEUM.

1 cubic foot oil, specific gravity 800 = 1·3817 pood.
" " " 850 = 1·4680 "
" " " 900 = 1·5544 "

1 American barrel = 42 American gallons = 35 English gallons.
1 " " = approximately 8 poods of kerosene.

OFFICIAL TABLE OF WEIGHTS OF PETROLEUM PER CUBIC FOOT FOR OILS OF DIFFERENT SPECIFIC GRAVITIES.

(Passed by the Russian Minister of Finance in 1892.)

Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.	Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.	Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.
0·700	1·2000	0·750	1·2953	0·800	1·3817
0·701	1·2107	0·751	1·2971	0·801	1·3834
0·702	1·2124	0·752	1·2988	0·802	1·3851
0·703	1·2142	0·753	1·3005	0·803	1·3869
0·704	1·2159	0·754	1·3022	0·804	1·3886
0·705	1·2176	0·755	1·3040	0·805	1·3903
0·706	1·2193	0·756	1·3057	0·806	1·3920
0·707	1·2214	0·757	1·3074	0·807	1·3938
0·708	1·2228	0·758	1·3091	0·808	1·3955
0·709	1·2245	0·759	1·3109	0·809	1·3972
0·710	1·2262	0·760	1·3126	0·810	1·3990
0·711	1·2280	0·761	1·3143	0·811	1·4007
0·712	1·2297	0·762	1·3161	0·812	1·4024
0·713	1·2314	0·763	1·3178	0·813	1·4041
0·714	1·2331	0·764	1·3195	0·814	1·4059
0·715	1·2349	0·765	1·3212	0·815	1·4076
0·716	1·2366	0·766	1·3230	0·816	1·4093
0·717	1·2383	0·767	1·3247	0·817	1·4110
0·718	1·2401	0·768	1·3264	0·818	1·4128
0·719	1·2418	0·769	1·3281	0·819	1·4145
0·720	1·2435	0·770	1·3299	0·820	1·4162
0·721	1·2452	0·771	1·3316	0·821	1·4179
0·722	1·2470	0·772	1·3333	0·822	1·4197
0·723	1·2487	0·773	1·3350	0·823	1·4214
0·724	1·2504	0·774	1·3368	0·824	1·4231
0·725	1·2521	0·775	1·3385	0·825	1·4249
0·726	1·2539	0·776	1·3402	0·826	1·4266
0·727	1·2556	0·777	1·3420	0·827	1·4283
0·728	1·2573	0·778	1·3437	0·828	1·4300
0·729	1·2591	0·779	1·3454	0·829	1·4318
0·730	1·2608	0·780	1·3471	0·830	1·4335
0·731	1·2625	0·781	1·3489	0·831	1·4352
0·732	1·2642	0·782	1·3506	0·832	1·4369
0·733	1·2660	0·783	1·3523	0·833	1·4387
0·734	1·2677	0·784	1·3540	0·834	1·4404
0·735	1·2694	0·785	1·3558	0·835	1·4421
0·736	1·2711	0·786	1·3575	0·836	1·4439
0·737	1·2729	0·787	1·3592	0·837	1·4456
0·738	1·2746	0·788	1·3610	0·838	1·4473
0·739	1·2763	0·789	1·3627	0·839	1·4490
0·740	1·2784	0·790	1·3644	0·840	1·4508
0·741	1·2798	0·791	1·3661	0·841	1·4525
0·742	1·2815	0·792	1·3679	0·842	1·4542
0·743	1·2832	0·793	1·3696	0·843	1·4559
0·744	1·2850	0·794	1·3713	0·844	1·4577
0·745	1·2867	0·795	1·3730	0·845	1·4594
0·746	1·2884	0·796	1·3748	0·846	1·4611
0·747	1·2901	0·797	1·3765	0·847	1·4630
0·748	1·2919	0·798	1·3782	0·848	1·4646
0·749	1·2936	0·799	1·3800	0·849	1·4663

OFFICIAL TABLE OF WEIGHTS OF PETROLEUM—(*continued*).

Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.	Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.	Specific gravity of liquid at 12° R. = 15° C.	Weight in poods per cubic foot.
0·850	1·4680	0·885	1·5285	0·920	1·5889
0·851	1·4698	0·886	1·5302	0·921	1·5907
0·852	1·4715	0·887	1·5319	0·922	1·5924
0·853	1·4732	0·888	1·5337	0·923	1·5941
0·854	1·4749	0·889	1·5354	0·924	1·5958
0·855	1·4767			0·925	1·5976
0·856	1·4784	0·890	1·5371	0·926	1·5993
0·857	1·4801	0·891	1·5388	0·927	1·6010
0·858	1·4819	0·892	1·5406	0·928	1·6027
0·859	1·4836	0·893	1·5423	0·929	1·6045
		0·894	1·5440		
0·860	1·4853	0·895	1·5458	0·930	1·6062
0·861	1·4870	0·896	1·5475	0·931	1·6079
0·862	1·4888	0·897	1·5492	0·932	1·6097
0·863	1·4905	0·898	1·5509	0·933	1·6114
0·864	1·4922	0·899	1·5527	0·934	1·6131
0·865	1·4939			0·935	1·6148
0·866	1·4957	0·900	1·5544	0·936	1·6166
0·867	1·4974	0·901	1·5561	0·937	1·6183
0·868	1·4991	0·902	1·5578	0·938	1·6200
0·869	1·5008	0·903	1·5596	0·939	1·6217
		0·904	1·5613		
0·870	1·5026	0·905	1·5630	0·940	1·6235
0·871	1·5043	0·906	1·5648	0·941	1·6252
0·872	1·5060	0·907	1·5665	0·942	1·6269
0·873	1·5078	0·908	1·5682	0·943	1·6287
0·874	1·5095	0·909	1·5699	0·944	1·6304
0·875	1·5112			0·945	1·6321
0·876	1·5129	0·910	1·5717	0·946	1·6338
0·877	1·5147	0·911	1·5734	0·947	1·6356
0·878	1·5164	0·912	1·5751	0·948	1·6373
0·879	1·5181	0·913	1·5768	0·949	1·6390
		0·914	1·5786		
0·880	1·5198	0·915	1·5803		
0·881	1·5216	0·916	1·5820		
0·882	1·5233	0·917	1·5838		
0·883	1·5250	0·918	1·5855		
0·884	1·5268	0·919	1·5872		

1 cubic foot of water at 12° R. or 15° C. = 1·7271 pood.
1 ,, ,, crude oil ,, ,, = 1·5 ,, *

CORRECTIONS OF SPECIFIC GRAVITY OF OIL FOR TEMPERATURE.

For each degree Centigrade rise of temperature specific gravity decreases by 0·0008.
,, ,, Fahrenheit ,, ,, ,, ,, 0·00044.
,, ,, Réaumur ,, ,, ,, ,, 0·001.

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* This figure is generally taken as the weight of mixed crude oil on the Baku properties. All reservoirs for crude oil are calculated on this basis.

TABLE OF BAUMÉ AND SPECIFIC GRAVITY EQUIVALENTS.*

Baumé.	Sp. gravity.	Baumé.	Sp. gravity.	Baumé.	Sp. gravity.
10	1·0000	37	0·8395	64	0·7243
11	0·9930	38	0·8346	65	0·7205
12	0·9860	39	0·8299	66	0·7168
13	0·9790	40	0·8251	67	0·7133
14	0·9722	41	0·8204	68	0·7097
15	0·9658	42	0·8157	69	0·7061
16	0·9594	43	0·8110	70	0·7025
17	0·9530	44	0·8063	71	0·6990
18	0·9466	45	0·8017	72	0·6956
19	0·9402	46	0·7971	73	0·6923
20	0·9339	47	0·7927	74	0·6889
21	0·9280	48	0·7883	75	0·6856
22	0·9222	49	0·7838	76	0·6823
23	0·9163	50	0·7794	77	0·6789
24	0·9105	51	0·7752	78	0·6756
25	0·9047	52	0·7711	79	0·6722
26	0·8989	53	0·7670	80	0·6689
27	0·8930	54	0·7628	81	0·6656
28	0·8872	55	0·7587	82	0·6619
29	0·8814	56	0·7546	83	0·6583
30	0·8755	57	0·7508	84	0·6547
31	0·8702	58	0·7470	85	0·6511
32	0·8650	59	0·7432	86	0·6481
33	0·8597	60	0·7394	87	0·6451
34	0·8544	61	0·7557	89	0·6422
35	0·8492	62	0·7319	89	0·6392
36	0·8443	63	0·7281	90	0·6363

TABLE FOR CONVERTING COPECKS PER POOD INTO £ *s.* *d.* PER TON.

Copecks per pood.	Price per ton.			Copecks per pood.	Price per ton.			Copecks per pood.	Price per ton.		
	£	*s.*	*d.*		£	*s.*	*d.*		£	*s.*	*d.*
1	0	1	3·802	18	1	3	8·4	35	2	6	1·0
2	0	2	7·6	19	1	5	0·2	36	2	7	4·8
3	0	3	11·4	20	1	6	4·0	37	2	8	8·6
4	0	5	3·2	21	1	7	7·8	38	2	10	0·4
5	0	6	7·0	22	1	8	11·6	39	2	11	4·2
6	0	7	10·8	23	1	10	3·4	40	2	12	8·0
7	0	9	2·6	24	1	11	7·2	41	2	14	11·8
8	0	10	6·4	25	1	12	11·0	42	2	15	3·6
9	0	11	10·2	26	1	14	2·8	43	2	16	7·4
10	0	13	2·0	27	1	15	6·6	44	2	17	11·2
11	0	14	5·8	28	1	16	10·4	45	2	19	3·0
12	0	15	9·6	29	1	18	2·2	46	3	0	6·8
13	0	17	1·4	30	1	19	6·0	47	3	1	10·6
14	0	18	5·2	31	2	0	9·8	48	3	3	2·4
15	0	19	9·0	32	2	2	1·6	49	3	4	6·2
16	1	1	0·8	33	2	3	5·4	50	3	5	10·1
17	1	2	4·6	34	2	4	9·2				

The table has been calculated on the basis that £1 = 9·45 roubles; 1 pood = 36 lbs.

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* From Boverton Redwood's "Petroleum."

RECENT DEVELOPMENTS IN THE RUSSIAN PETROLEUM INDUSTRY.

SINCE this work has been in the press, such important events and such momentous developments have taken place in the petroleum industry, that a brief outline of these changes is necessary to bring the book up to date. The period under review has not lacked interest to the most phlegmatic observer; indeed, it might be said that the latter half of 1903 has been one of the most exciting times in the petroleum industry on record.

During the summer of 1903, a strike broke out in the Baku district, which assumed such proportions that all work on the oil fields was suspended for several weeks. The strikers, in the absence of an adequate number of police and soldiers, compelled the peacefully disposed employees to cease work on the oil properties, and many acts of violence and incendiarism were enacted by the less orderly section of the strikers. The Baku oil producers must have sustained a loss of fully £200,000, through damage to property and absence of production, before the strike was suppressed and order restored.

The autumn was eventful on account of the numbers of huge fires which devastated the oil fields time after time, causing the destruction of millions of poods of oil, and sweeping away dozens of derricks, and also for one or two wonderful fountains of prodigious yield. In one conflagration at Bibi-Eibat three fountains were burning simultaneously, one of which was estimated to be yielding nearly 1,000,000 poods a day. At another time a Bibi-Eibat fountain was burning furiously for three weeks before it became plugged and was extinguished.

The chief event of the year was, however, the unexpected and unprecedented rapid rise in the prices of Russian petroleum products, the quotations in the winter of 1903 almost equalling the figures when the boom was at its zenith in 1900. The events which were instrumental in bringing about this change can only be understood when the conditions of the other oil-producing countries are considered. There is a constantly growing demand for petroleum products, owing to the great advancement in oil- and spirit-engines. Oil-engines are daily becoming more popular for small powers, and motor-cars are causing an ever-increasing market for the lighter products, the extraction of which, in many oil fields, has hitherto been quite neglected. Until the last few years, the United States has practically supplied the world (excepting Russia) with oil, but the American home demand is advancing with such strides that there is annually a smaller surplus of oil for export.

The 1903 statistics are not yet issued, but in 1902 the world's production of petroleum was approximately 181,381,000 barrels, made up as follows:—

Russia	84,000,000 barrels.
United States	80,895,000 ,,
Sumatra, Java, Borneo, etc.	5,860,000 ,,
Galicia	4,142,000 ,,
Roumania	2,480,000 ,,
India	1,571,000 ,,
Japan	1,190,000 ,,
Canada	520,000 ,,
Germany	625,000 ,,
Peru	60,000 ,,
Other countries	38,000 ,,

The Standard Oil Co. of America practically monopolizes the distribution and sale of American petroleum products, and in England this huge enterprise has spent millions in perfecting its arrangements for distribution. For some time the Standard Oil Co. has, it is reported, been obliged to supplement its American supplies with European oils; indeed, there has been a marked decline in American imports, as will be seen by the table below:—

IMPORTS OF PETROLEUM INTO ENGLAND (IN BARRELS).

	American.	Russian.	Roumanian.
1898	2,843,500	915,400	—
1899	2,701,800	1,340,400	—
1900	2,657,500	1,300,000	—
1901	2,619,300	1,200,300	51,500
1902	2,515,100	1,732,500	65,500
1903	2,083,600	2,202,100	31,000

It is anticipated that the United States statistics for 1903 will show a substantial increase over the preceding year, the estimated amount of crude oil being 100,000,000 barrels. It should be noted that a considerable proportion of the Texas and Californian oils included in the above estimate is best suited for fuel, and is not very rich in illuminating products. The Pennsylvanian oil fields show a falling off; Texas has not fulfilled expectations; and were it not for the wonderful and unexpected results obtained in California, a large deficit would have been occasioned.

In the autumn of 1903 it was generally reported that the stocks of the Standard Oil Co. were being lowered, and as there were small prospects of filling the shortage in America, purchases would have to be made on a large scale in Europe. The Standard Co.'s agents who visited Roumania were treated with unconcealed resentment by the Government, but nevertheless it is an open secret that this company has purchased no inconsiderable interests in the country, and intends to assist and encourage the small producers. In Baku heavy purchases of kerosene were made at low prices by the Standard Co.'s agents, causing an almost immediate rise of prices, a rise which was steadily maintained until kerosene stood at 36 copecks per pood. Crude oil rose in sympathy with the refined product from an average of 8 copecks to as much as 16 copecks, and for the first time since the eventful June of 1900, Russian oil producers saw bright prospects ahead.

The revolution wrought in the Russian petroleum industry in the course of a few months has been commonly attributed to the presence of American buyers. Such does not seem to have been altogether the reason. Production had fallen in the Baku oil fields; there had been for some time a tendency for prices to harden; and it was largely due to the intense pessimism and the great feverishness displayed by the

Baku merchants that the long-awaited improvement was delayed. The advent of American buyers, with a plentiful supply of ready money, served to give the Baku merchants the courage they lacked, with results that all oil-men are acquainted with. The altered conditions in the petroleum world may have the effect of directing greater attention to Russian oils. The United States can no longer supply Europe with petroleum, unless, as seems improbable, other large oil fields are opened up. Russia is the only other country which yields at the present time, and is likely to produce for many years, large quantities of petroleum, so that it seems probable that a period of prosperity lies ahead of the Russian oil industry, provided the Government places no serious restrictions on exports.

A further and far-reaching result is achieved by the altered conditions. The greatly enhanced value of kerosene will cause a larger quantity of this distillate to be extracted from the crude oil. Lucrative employment will be found for the refineries, and the high price of refined products will allow astatki to be sold at a price of 10 to 12 copecks per pood, with good margin for profits, and Russian industries relying upon liquid fuel will not suffer.

Renewed activity is displayed in every department of the Russian petroleum industry, and Baku is once more beginning to wear its old air of prosperity. Unfortunately, at the very moment when prospects appear brightest, negotiations between Russia and Japan have been suddenly broken off and war has been declared. How much this will affect the petroleum industry of Russia no one can say; but widespread regret must be felt that no simpler solution of the disputes between the two could be found.

Grosny has received welcome news by the announcement that Mr. MacGarvey, one of the most practical and enterprising oil producers in Europe, has struck oil at a point situated several miles further along the Grosny range. Although the stratum is deep, and its practical worth not yet established, the well furnishes valuable information concerning the disposition of the Grosny beds.

Berekei has been proved to repay exploitation, and considerable interest has been manifested in this new oil field by Baku oil producers. Messrs. Nobels have purchased a large number of plots in the region, and are making preparations for further exploitation.

Reports from Baku also confirm the news that a small fountain has been struck at Maili-Sai in the Fergana region of Turkestan. The depth of the well is only 123 sagenes, and oil flows every 12 to 15 minutes to a height of 70 feet.

This work has been almost exclusively confined to a description of the Russian petroleum industry; but recent developments have so modified one important branch of the oil trade, which must affect to some degree the Russian business, that a brief account cannot fail to be of interest to some readers.

In the United States, for many years, water-gas, enriched by means of petroleum, has formed the largest part of the ordinary town supply; at the present time it forms about 80 per cent. of the total gas distributed. This gas, known as carburetted water-gas, is almost exclusively manufactured by what is known as the Lowe process. During the past 12 years this process has become so popular in many of the large English gas-works that a considerable demand for a special class of oil has been created.

The cost of this carburetted water-gas, as compared with common coal-gas, depends almost entirely upon local conditions. In many places it is considerably cheaper than the coal-gas, even though it possesses greater illuminating effect; but even where its cost is greater than that of coal-gas, the auxiliary manufacture of carburetted water-gas effects reflex economies in the cost of the coal-gas, and this advantage cannot be ignored by practical gas engineers. One of its special advantages is that it forms a valuable consumer of coke, thus controlling the coke market. The chief advantages, however, of a carburetted water-gas plant are the simplicity, cheapness, small space occupied by the apparatus, and the means with which the ordinary supply of coal-gas may be supplemented at very short notice. If a breakdown occurs, or a fog suddenly envelops a district, an increased demand for gas is thrown upon the resources of the gas-works, and it is the carburetted water-gas plant that permits the deficiency to be made good in a very short space of time. By thus taking up the fluctuations in the demand, it allows the coal-gas works to be operated under the most economical conditions.

The manufacture of carburetted water-gas may briefly be described as an enrichment of water-gas by means of passing steam through incandescent coke, the carburetting agent being either crude oil, solar oil, or kerosene.

In the Humphreys-Glasgow carburetted water-gas plant there are three cylindrical vessels, known as the generator, carburetter, and superheater respectively. The generator contains coke; the carburetter and superheater are filled with firebricks placed so as to form checker-work. An air blast, generated by a fan or blower, is admitted beneath the grate in the generator, and the ignited coke is thus brought to a state of intense incandescence, and the gaseous products of combustion are conducted through the second and third vessels, and thence to the smoke-stack. A portion of the heat energy of the coke is appropriated for the gasification of the oil. This is accomplished by so adjusting the strength and length of the blast that a sufficient quantity of carbon monoxide remains in the blast products to be consumed in the carburetter and superheater checker-work by the admission of secondary air. When the fuel in the generator and the checker brick in the gas-fixing chambers have reached the proper temperature, the air supply is cut off, and steam is admitted to the generator. This steam, on coming into contact with the incandescent carbon, is dissociated, with the ultimate formation of a gas composed of about 43 per cent. of carbon monoxide, 50 per cent. of hydrogen, and small percentages of nitrogen and carbon dioxide. This gas meets with a spray of oil, previously heated, at its entrance at the top of the carburetter, and the combined mixture passes through the numerous interstices of the heated checker brickwork. By the time that the passage through the checker work is completed, the oil has been thoroughly broken up and gasified, the resulting product being a gas which is chemically the same as coal-gas, although the constituents exist in somewhat different proportions. From the outlet of the superheater, the carburetted water-gas passes on to washers, scrubbers, condensers, purifiers, etc., the same as in coal-gas manufacture.

An arrangement of valves and connections is provided so that the steam may be made to pass either in an upward direction or in a downward direction through the fire as desired, the object of this being to maintain a proper distribution of heat in the incandescent fuel bed.

When the coke and checker-work are reduced in temperature to a point which does not allow of the proper dissociation of steam and gasification of the oil, the steam and oil are shut off, and air is again admitted, and the process of recuperating the heat in the fuel bed and the checker brick is repeated. The complete cycle of events occupies under normal conditions about 10 minutes, that is, 3 minutes for blowing up heats, and 7 minutes for gas-making. Practically no time is occupied in making the changes, as the whole operation is automatically performed by interlocked mechanism.

From 2½ to 3 gallons of oil and from 30 to 40 lbs. of coke are consumed per 1000 cubic feet of gas produced. Russian residual oils, and especially the solar distillate, have always been popular gas oils in the English and European markets, as they possess the qualities essential to a good gas-making oil. Russian solar oil is homogeneous, it is practically free from sulphur and water, and produces no solid residue on gasification, and it splits up into permanent gases at a moderate heat and over a fairly wide range of temperatures. Another advantage that it possesses is that the residual oil tar produced from it contains a very small percentage of light products, such as benzol or naphthalene, and is therefore readily separated from the water. About 2,000,000 poods of gas-making oils are now used annually in the United Kingdom, and as there is a continual increase in the manufacture of carburetted water-gas, the demand in the future will be still greater.

The latest departure in the use of petroleum for gas-making is likely to receive considerable attention during the next few years, and still further create a demand for Russian distillates. A process has been invented and patented by Mr. W. J. Dibdin, F.I.C., in conjunction with Dr. Wolterick, by means of which oil can be converted into a permanent gas, having almost the identical qualities and composition as coal-gas, and being unrecognizable from coal-gas.

A jet of steam and oil is injected into a retort containing iron maintained at a bright red heat by means of a furnace beneath the retort. The steam is decomposed by the heated iron, with the formation of hydrogen and oxide of iron. The oxide of iron thus primarily produced is reduced by the petroleum vapour which accompanies the steam, and the gases are by this means dissociated into hydrocarbons containing a lower percentage of carbon. The process is continuous, the decomposition of the steam and reduction of the oil vapour proceeding simultaneously, and practically the whole of the oil is converted into gas, leaving scarcely a trace of residuals.

Unlike carburetted water-gas, this gas contains about the same amount of carbon monoxide as coal-gas, and is so similar to coal-gas that it is scarcely distinguishable from it. The illuminating effect of the gas can be varied to almost any limit at the expense of oil. 100,000 cubic feet of 16 candle-power gas can be made from a ton of Russian solar distillate.

In this process there is no need for coal or coke, and petroleum may be used throughout as fuel. Such a plant should have an extensive demand in Russian districts where coal is scarce and oil is cheap. Even Baku, with a population of over 100,000 people, is still unprovided with a gas or public electric light supply, the streets being illuminated with oil-lamps.

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